

AT MICROFICHE
REFERENCE
LIBRARY

A project of Volunteers in Asia

Design Problems for Simple Rural Water Systems

by: A. Scott Faiia

Published by:

A. Scott Faiia
CARE Lombok
Jalan Veteran 1
Mataram, Lombok
Indonesia

Available from:

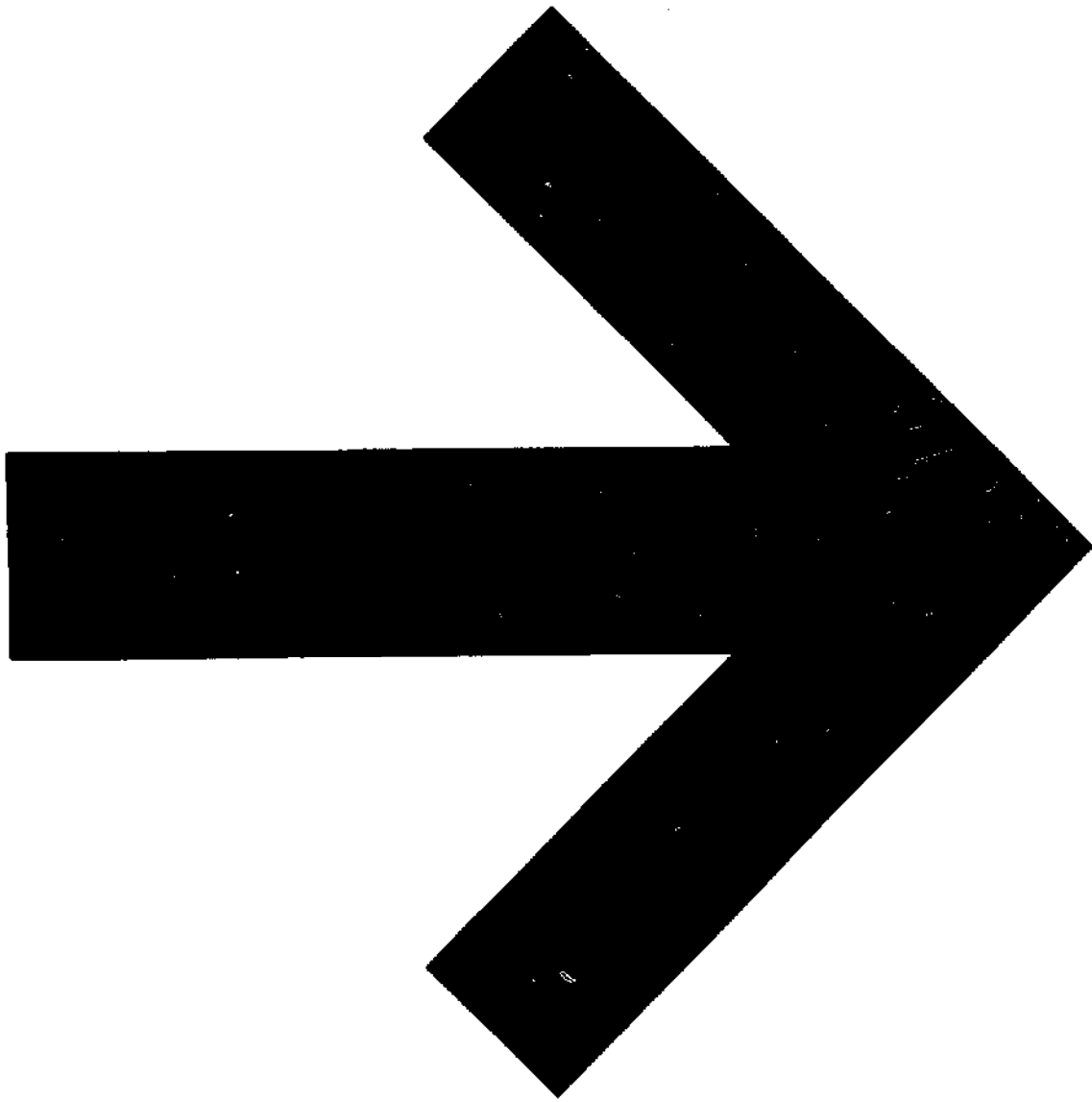
A. Scott Faiia
CARE Lombok
Jalan Veteran 1
Mataram, Lombok
Indonesia

Reproduction of this microfiche document in any form is subject to the same restrictions as those of the original document.

DESIGN PROBLEMS
FOR
SIMPLE RURAL WATER SYSTEMS

A. SCOTT FAHA
Sanitary Engineer

1982



C O N T E N T S

- P.1. Average Daily Usage, Average Daily Flow
- P.2. Storage Volume and Placement
- P.3. Use of RPT for Storage
- P.4. Flow in GI and PVC Pipes
- P.5. Flow in Different Pipe Diameters
- P.6. Flow For Different Lengths of Pipe
- P.7. Flow for Different Available Head
- P.8. Choosing a Design Flow
- P.9. Choosing a Design Flow
- P.10. Plotting the HGL and Pressure in the Pipeline
- P.11. Estimating Flow in the Pipeline
- P.12. Estimating Flow in the Pipeline
- P.13. Selecting Appropriate Pipe Sizes
- P.14. Selecting Appropriate Pipe Sizes
- P.15. Negative Pressure in the Pipeline
- P.16. Eliminating Negative Pressure in the Pipeline
- P.17. Plotting the HGL for Different Configurations of Pipe
- P.18. Selecting Appropriate Pipe Sizes
- P.19. Location of Break Pressure Tanks
- P.20. System Design for Storage at the Source
- P.21. System Design for Storage Above the Village but Below the Source
- P.22. System Design for Storage at the Point of Use.
- P.23. Cost Comparison of Designs with Various Storage Options

INTRODUCTION

This booklet contains a series of 24 design problems for gravity flow water systems. The problems are labeled from P.1. to P.24. and are followed by proposed solutions which are labeled from S.1. to S.24. The proposed solutions are based upon guidelines recommended in "Gravity Flow Water Systems - Practical Design Notes for Rural Water Systems" and are only appropriate if the guidelines are also appropriate for the area. Furthermore, each design problem confronted in the field is unique and will require its own solution. Therefore, the solutions are primarily intended to illustrate general principles and stimulate thinking and discussion about design problems in rural water systems. Through thinking and discussion a better understanding will be obtained and it is this understanding that makes a good designer.

P.1. A village of 2,000 people is to be supplied with 80 liters of water per person per day.

- a. What is the average daily usage ?
- b. What is the average daily flow ?

S.1. a. The average daily usage is 2,000 persons x 80 liters or 160,000 liters. There are 1,000 liters per m³ so this is equivalent to 160 m³. This is the amount of water that would be used in one day if each person used exactly 80 liters.

b. The average daily flow is the flow of water required to supply the average daily usage. There are 60 x 60 x 24 or 86,400 seconds per day. The number of liters per day divided by this will give the average daily flow in l/s. Thus 160,000 liters/day ÷ 86,400 second/day is equal to 1.85 liters/second and this is the average daily flow. To convert average daily usage in m³ to average daily flow in l/s divide by 86.4

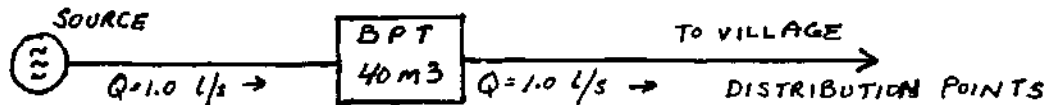
P.2. A water system for a transmigration village is planned that will provide 1,200 persons with 80 liters of water per day. The village will consist of seven kampongs. Two kampongs having populations of 250 persons, four having populations of 150, and one having a population of 100. The estimated minimum flow of the water source is 1.5 l/s.

- a. What is the recommended storage volume ?
- b. Where should the storage be located ? Suggest two alternatives.

S.2. a. If 1,200 persons use 80 liters per day then the average daily usage is 96 m³ and the average daily flow is 1.1 l/s. The recommended storage is one half of the average daily usage or 48 m³.

b. The storage could all be located at the source or at a single point sufficiently high above the village. However, it could also be located within the village at the point of use. In this case it would be divided according to the population density for each kampong. Thus, the two kampongs with 250 persons would have a storage capacity of $500 \div 1200 \times 48$ or 19.9 m³. These two kampongs could each have one reservoir of 10 m³ capacity. The four kampongs with populations of 150 would have a storage capacity of $600 \div 1,200 \times 48$ or 24 m³. These four kampongs could each have one reservoir of 6 m³ capacity. The remaining kampong of 100 persons would have one 4 m³ storage reservoir so the total storage capacity would be 48 m³.

P.3. In the water system for Desa Ibu Kota the average daily flow is 1 l/s. The water will flow from the source to a break pressure tank (BPT) located 1,000 meters from the source. Water from the BPT will flow to distribution points in the village. The design engineer has chosen a design flow of 1 l/s from the source to the BPT and the same design flow of 1 l/s from the BPT to the village. He has also fixed the volume of the BPT at 40 m³ to provide storage for the system. A sketch of the situation is included in the figure below.



- a. Is it possible for a BPT to also function as a storage reservoir ?
- b. Does the BPT for Desa Ibu Kota described above function as a storage reservoir ?

S.3.a. Yes it is possible for a BPT to serve as a storage reservoir. However, the design flows entering and leaving the reservoir must be appropriate.

- b. No, the BPT for Desa Ibu Kota does not function as a storage reservoir. This is because the design flows entering and leaving the reservoir are the same. If the BPT is to function as a reservoir then the design flow for the pipe leaving it should be greater than the design flow for the inflow. In the case of desa Ibu Kota the engineer should either provide storage in the village and reduce the size of the BPT to 1 m³ or allow the BPT to function as a storage reservoir feeding village standpipes by increasing the design flow for the outflow from the BPT to 4 l/s.

P.4. Water is to be provided to a hotel located 2,000 meters from a spring. The spring is 20 meters higher in elevation than the hotel.

- a. What is the estimated flow of water to the hotel if 2 inch GI pipe is installed ?
- b. What is the estimated flow of the water to the hotel if 2 inch PVC pipe is installed ?

- S.4. From the water flow calculator the estimated flow is 1.1 l/s for 2 inch GI pipe and 1.4 l/s for 2 inch PVC pipe. The smoother surface of the plastic pipe allows for a greater flow of water even though the pipe size, distance, and available head are the same.
- P.5. Water is to be provided to a hotel located 2,000 meters from a spring. The spring is 20 meters higher in elevation than the hotel.
- What is the estimated flow of water to the hotel if 2 inch GI pipe were installed ?
 - What is the estimated flow of water to the hotel if a 1 inch GI pipe were installed ?
- S.5. From the water flow calculator the estimated flow is 1.1 l/s for 2 inch GI pipe and 0.165 l/s if 1 inch GI pipe were installed. A smaller diameter pipe will result in a smaller flow if other conditions are the same.
- P.6. Water is to be supplied from a spring to a village mosque. The spring is 20 meters higher in elevation than the mosque. A 1 inch GI pipe is to be used.
- What is the estimated flow of water if the distance from the source to the mosque is 500 meters?
 - What is the estimated flow of water if the distance from the source to the mosque is 1,000 meters ?
- S.6. From the water flow calculator the estimated flow for 500 meters is 0.34 l/s and for 1,000 meters 0.16 l/s. The greater the distance the water must flow, the smaller the amount of flow if other conditions remain the same.

P.7. Water is to be supplied from a spring to a village mosque 1,000 meters from the spring. A 1 inch GI pipe is to be used.

a. What is the estimated flow of water to the mosque if the available head is 10 meters.

b. What is the estimated flow of water to the mosque if it were first pumped into a 10 meter high tower thereby increasing the available head to 20 meters ?

S.7. From the water flow calculator the estimated flow for a 10 meter head loss is 0.16 l/s and for a 20 meter head loss, 0.24 l/s. The increased head allows a greater volume of water to flow when other conditions remain the same.

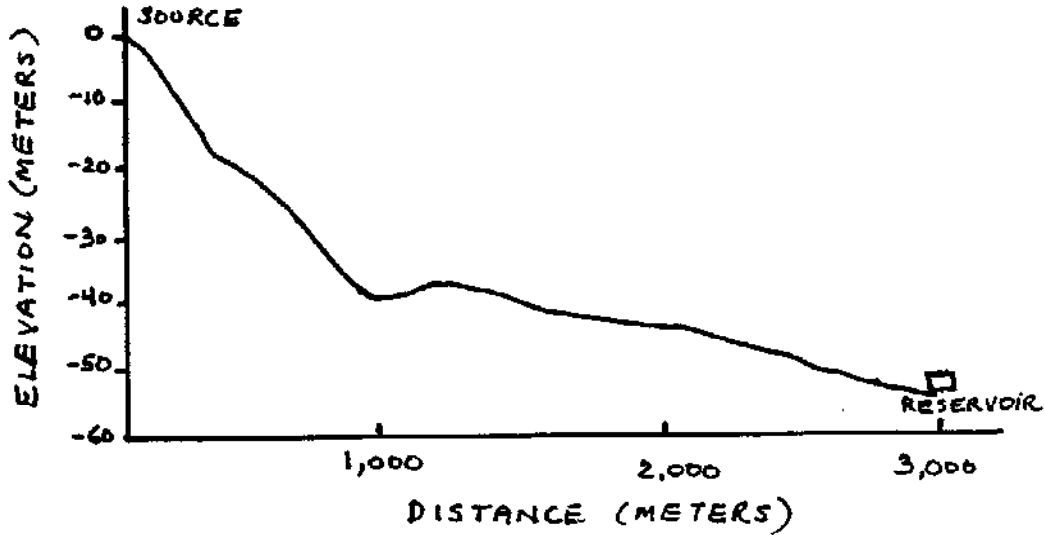
P.8. A kampong of 500 persons is to be supplied 100 liters per person per day of water. The storage reservoir is located at the water source. What is the recommended design flow for the main pipe from the storage reservoir to the first distribution point in the village ?

S.8. The average daily usage of the water is 500 persons x 100 liters or 50 m³. This is equivalent to an average daily flow of 0.58 l/s. Storage is at the source and the pipe is in use only when people are taking water from the faucets. Therefore the recommended design flow is four times the average daily flow of 0.58 l/s or 2.32 l/s.

P.9. A kampong of 500 persons is to be supplied with 100 liters per person per day of water. Two storage reservoirs will be located in the kampong. What is the recommended design flow for the main pipe from the source to the first storage reservoir ?

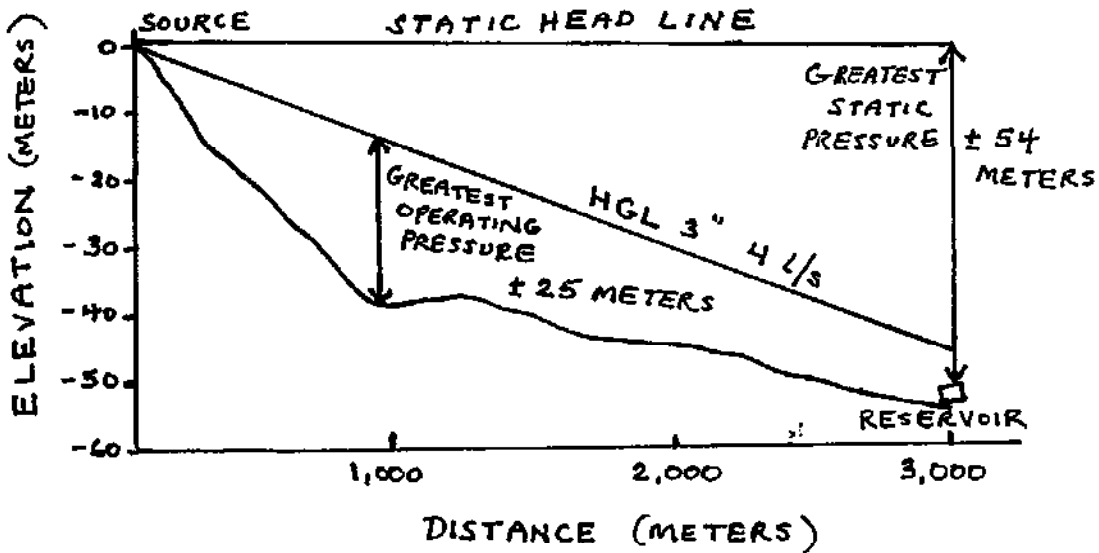
S.9. The average daily usage of water is 500 persons x 100 liters or 50 m³. This is equivalent to an average daily flow of 0.58 l/s. Since storage is located at the village the water is flowing into the reservoir 24 hours a day and the design flow to the first reservoir is the same as the average daily flow or 0.58 l/s.

P.10. Given the ground profile in the figure below plot the HGL for a design flow of 4 l/s using 3 inch GI pipe.



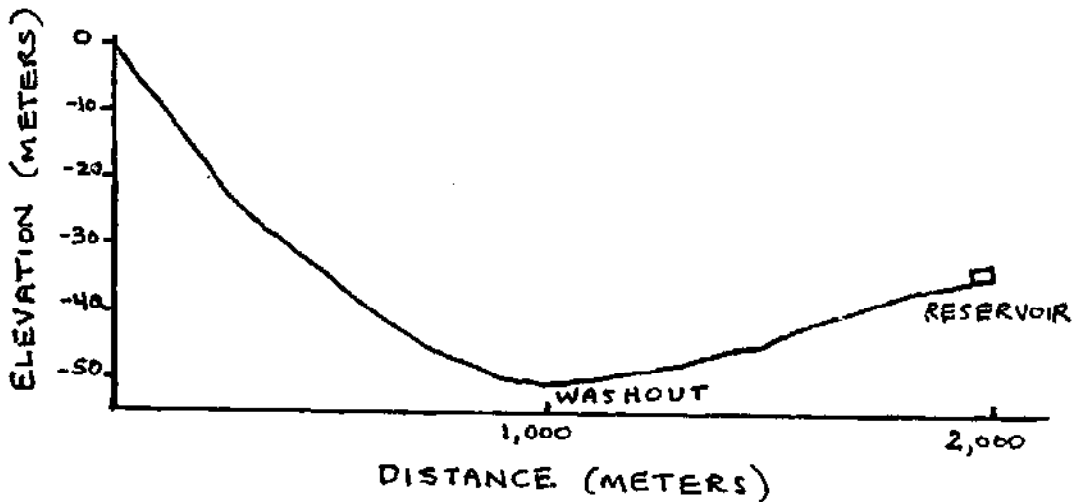
- a. At what point is the greatest operating pressure in the pipeline ?
- b. What is the greatest operating pressure in the pipeline ?
- c. Where does the greatest static pressure occur.
- d. What is the greatest static pressure in the pipeline ?

S.10. From the water flow calculator the head loss for 3,000 meters of 3 inch GI pipe with a flow of 4 l/s is 46 meters. The HGL is plotted in the figure below using the calculated head loss.



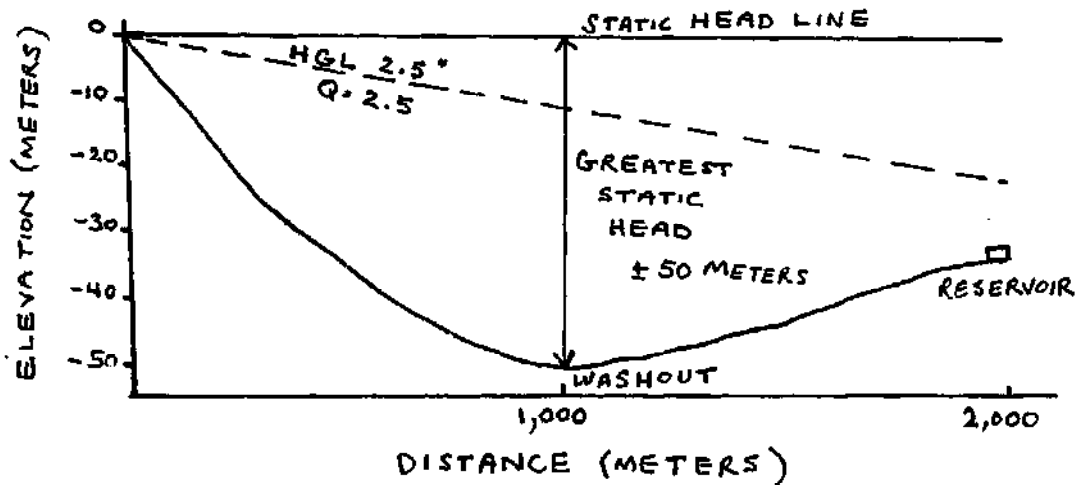
- a. The greatest operating pressure in the pipeline is at the point where the distance between the pipeline profile and the HGL is greatest. In this case it is at 1,000 meters from the source.
- b. The operating pressure at the point of greatest pressure is approximately 25 meters.
- c. The greatest static pressure occurs at the lowest point in the pipeline. In this case it is at the reservoir at the end of the pipeline.
- d. The greatest static pressure is the difference in elevation between the lowest point and the highest point. In this case it is approximately 54 meters.

P.11. Given the ground profile in the figure below plot the HGL for a 2.5 inch GI pipe. The design flow is 2.5 l/s.



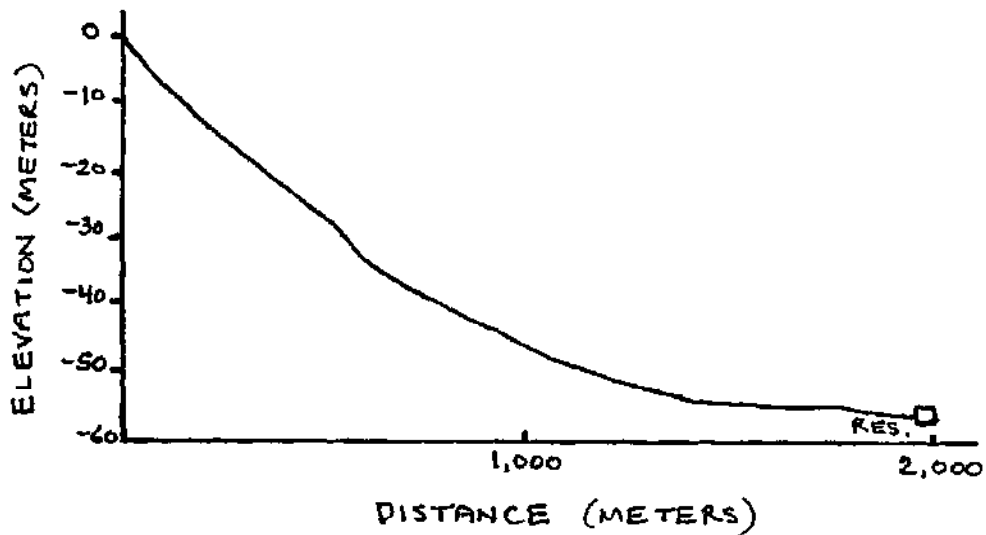
- a. Where is the point of greatest static pressure in the pipeline ?
- b. What is the greatest static pressure in the pipeline ?
- c. If the valve at the reservoir were closed and the washout at 1,000 meters fully opened what would be the estimated flow at the washout ?
- d. If the washout were closed and the valve at the reservoir fully opened what would be the estimated flow at the reservoir ?

S.11. From the water flow calculator the head loss for 2,000 meters of 2.5 inch GI pipe with a flow of 2.5 l/s is 22 meters. The HGL is plotted in the figure below using this head loss.

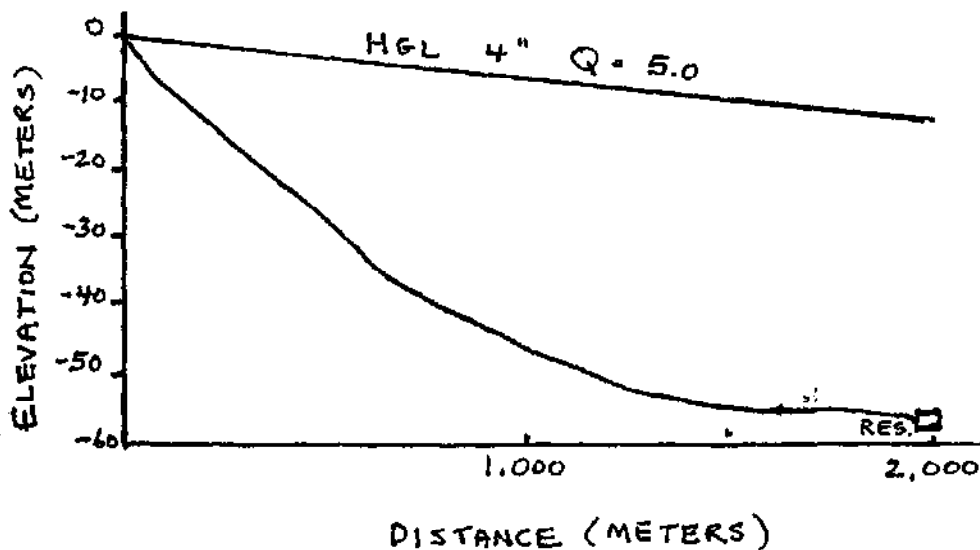


- a. The point of greatest static pressure is the lowest point in the pipeline. In this case it is 1,000 meters from the source.
- b. The greatest static pressure is the difference in elevation between the highest and lowest points. In this case it is approximately 50 meters of head.
- c. The washout is 1,000 meters from the source and the available head at this point is 50 meters. Using the water flow calculator 1,000 meters of 2.5 inch GI pipe with a 50 meter head loss indicates a flow of approximately 5.8 l/s.
- d. The reservoir is 2,000 meters from the source and the available head is 35 meters. Using the water flow calculator 2,000 meters of 2.5 inch GI pipe with a head loss of 35 meters indicates a flow of approximately 3.25 l/s. The increased distance and higher elevation of the reservoir reduce the flow of water to that point.

P.12. Given the ground profile in the figure below plot the HGL for 4 inch GI pipe with a flow of 5.0 l/s.

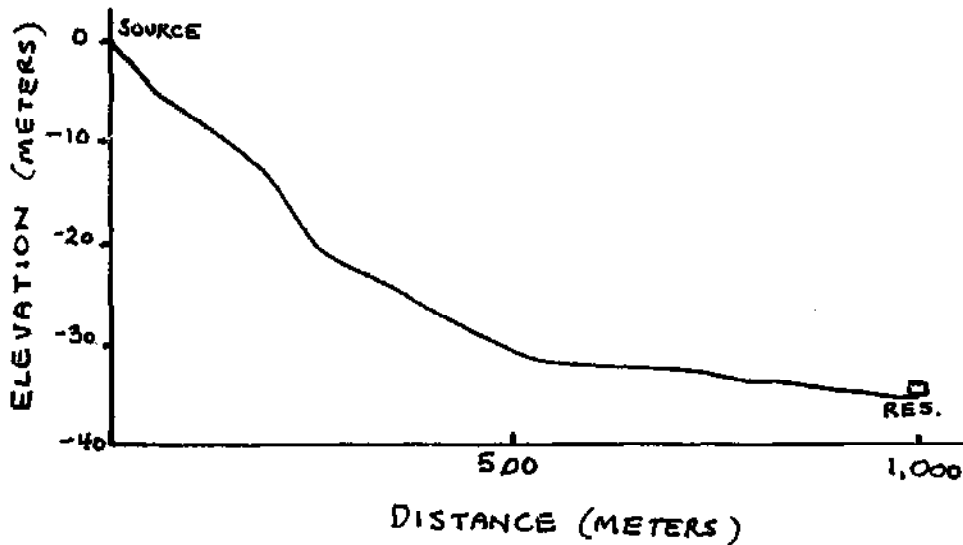


- a. If the flow of the source were 5.0 l/s what would happen if a 4 inch pipe were installed ?
 - b. If the flow of the source were 20 l/s what would happen if a 4 inch pipe were installed ?
 - c. If 5.0 l/s were the desired flow of water what is the most appropriate pipe diameter ?
- S.12. From the water flow calculator the head loss for 2,000 meters of 4 inch GI pipe with a flow of 5.0 l/s is 11 meters. The HGL is plotted on the figure below.



- a. If the flow of the source were 5.0 l/s then all of this water would flow to the reservoir if 4 inch pipe were installed. However, the pipe would be only partially full of water.
- b. The available head from the source to the reservoir is approximately 55 meters. On the water flow calculator 4 inch GI pipe for a distance of 2,000 meters and a head loss of 55 meters indicates a flow of approximately 12 l/s. Thus a 4 inch pipe could not accommodate the full flow of the source and the expected flow at the reservoir would be 12 l/s.
- c. Using the water flow calculator, 3 inch GI pipe for a distance of 2,000 meters and a flow of 5.0 l/s indicates a head loss of approximately 48 meters. The available head is approximately 55 meters. Thus, 3 inch GI pipe is suitable for the required flow.

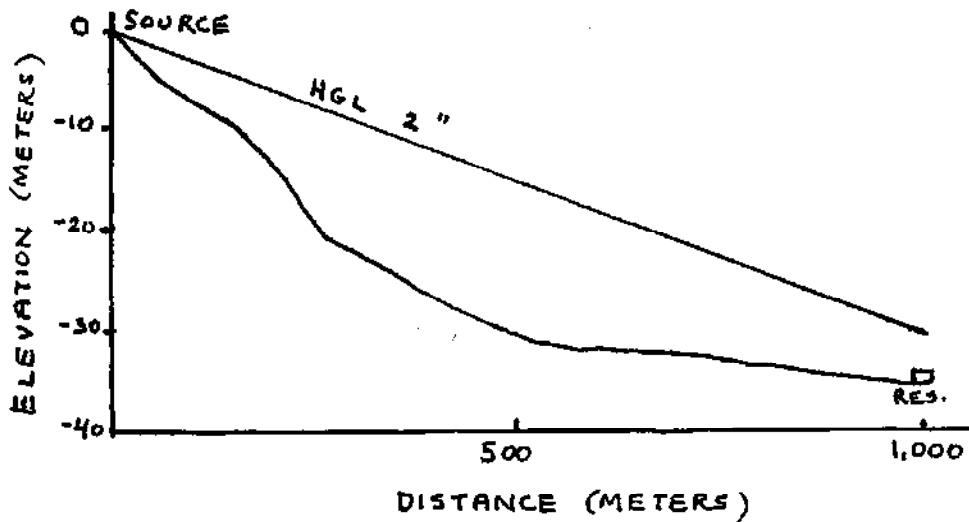
P.13. Given the ground profile in the figure below choose an appropriate pipe size for a flow of 2 l/s from the source to the reservoir. Plot the HGL.



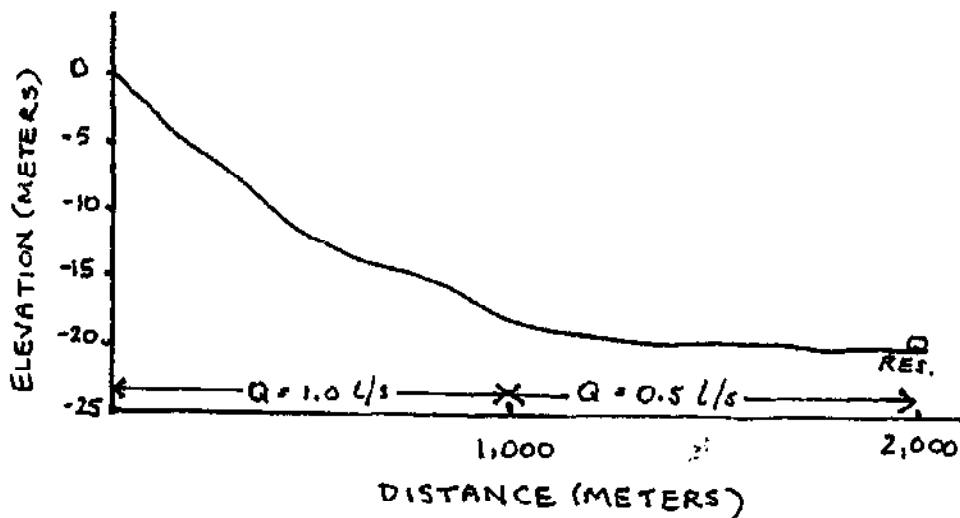
S.13. The available head from the source to the reservoir is approximately 35 meters. Using the water flow calculator the following values are obtained for a flow of 2 l/s using GI pipe :

Distance (meters)	pipe diameter (inches)	head loss (meters)
1,000	2.5	7
1,000	2	30
1,000	1.5	130

Thus a 2 inch GI pipe is suitable. The HGL is plotted on the figure below.



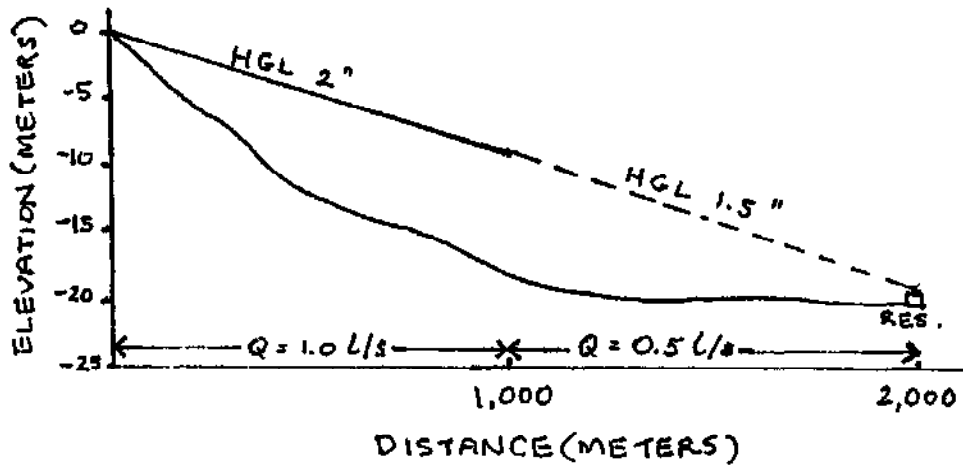
P.14. Given the ground profile and design flow in the figure below choose appropriate GI pipe. Plot the HGL for the pipe selected.



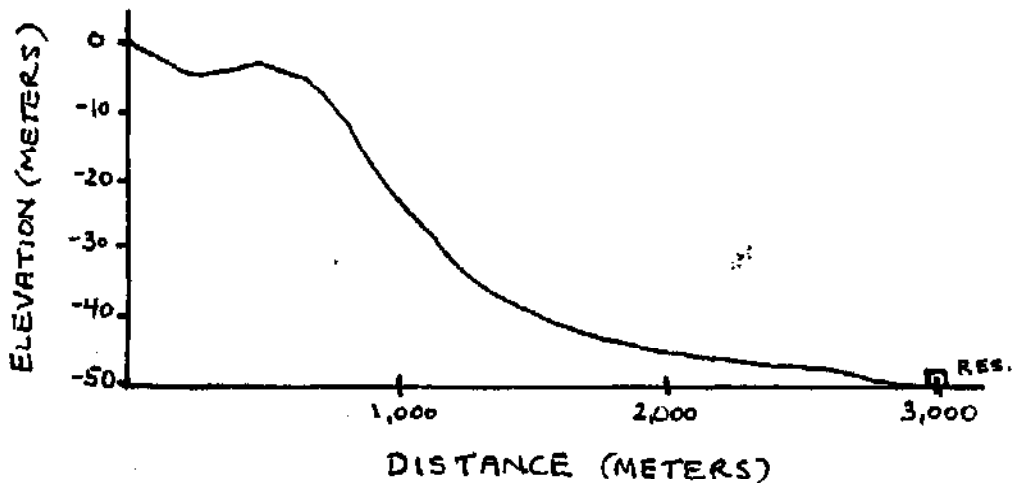
S.14. Using the water flow calculator the following values are obtained :

Distance (meters)	flow (l/s)	pipe diameter (inches)	head loss (meters)
1,000	1	2.5	2
1,000	1	2	9
1,000	1	1.5	36
1,000	0.5	2	2.5
1,000	0.5	1.5	10
1,000	0.5	1.25	24

The total available head is approximately 20 meters. Thus a combination of 1,000 meters of 2 inch and 1,000 meters of 1.5 inch pipe is appropriate. The HGL is plotted in the figure below.

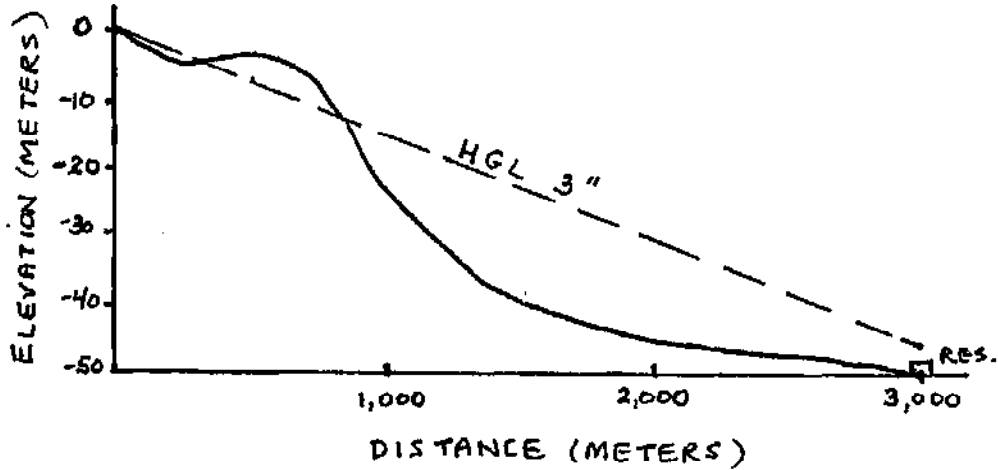


P.15. Given the ground profile in the figure below plot the HGL for a design flow of 4 l/s using 3 inch GI pipe.



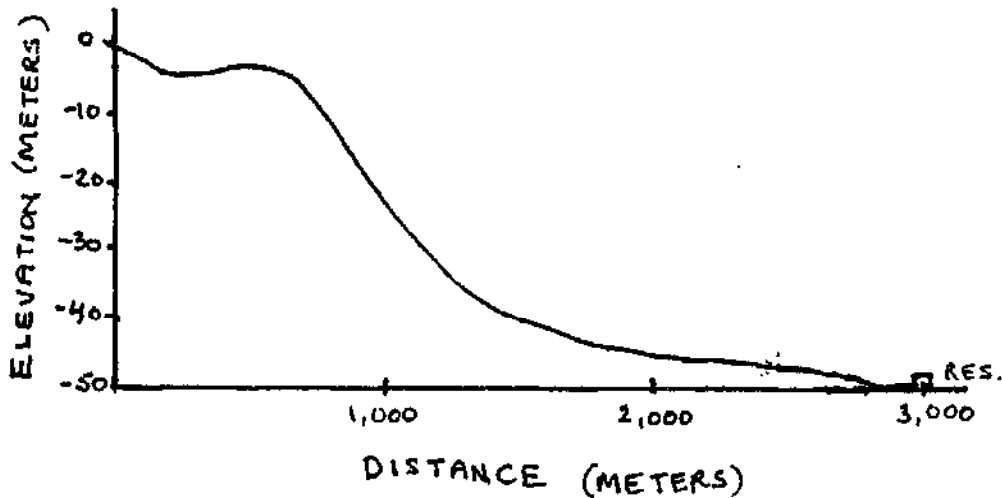
a. Is 3 inch pipe suitable in this situation ? What are the reasons?

S.15. From the water flow calculator the head loss for 3,000 meters of 3 inch GI pipe with a flow of 4 l/s is 46 meters. The HGL is plotted on the figure below using the calculated head loss.



a. If the 3 inch pipe follows the ground profile then it will lie above the HGL near the source. This means that there could be a negative pressure in the pipeline in this area. Thus, three inch pipe is not suitable.

P.16. Given the ground profile in the figure below choose an appropriate size of GI pipe for a design flow of 4 l/s.



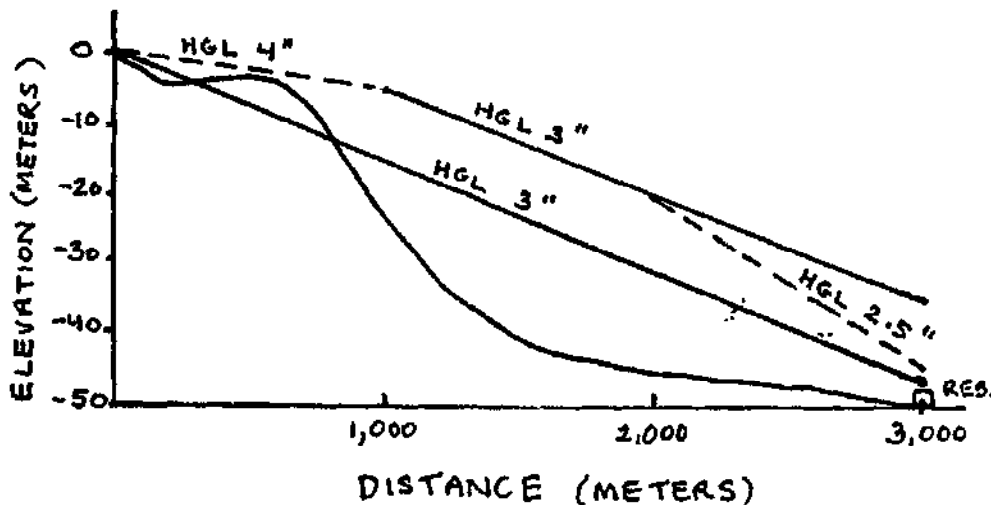
S.16. Using the water flow calculator the following values are obtained for a flow of 4 l/s.

Distance (meters)	pipe diameter (inches)	head loss (meters)
3,000	4	11
3,000	3	46
3,000	2.5	75

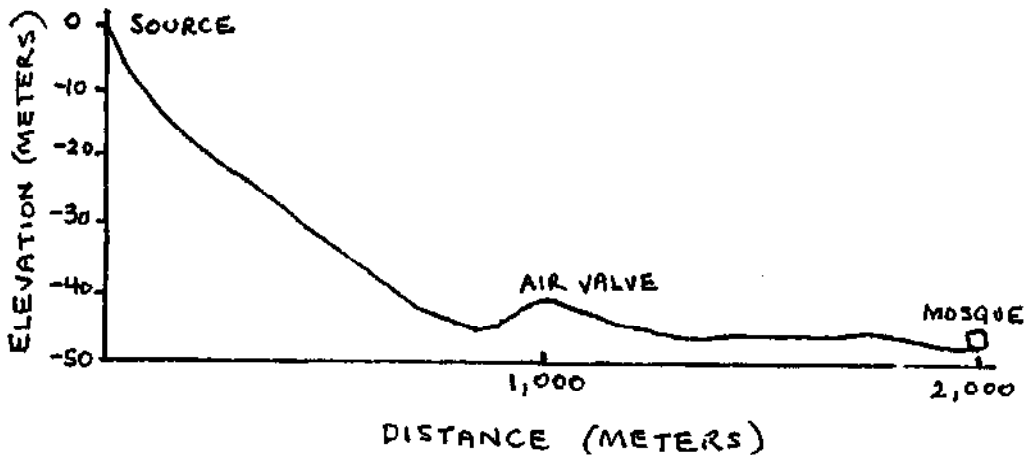
The head loss for 3 inch pipe closely matches the available head from the source to the reservoir but when the HGL is plotted on the figure below it falls below the ground profile near the source. This can result in negative pressure in the pipeline and is not allowable. Thus a larger diameter pipe must be used in this area. However, if pipe larger than 3 inch were used for the entire 3,000 meters it would be larger than needed and wasteful. To choose an appropriate size pipe the following values are obtained from the water flow calculator for a flow of 4 l/s.

distance (meters)	pipe diameter (inches)	head loss (meters)
1,000	4	4
2,000	3	30
1,000	3	16
1,000	2.5	25

If 1,000 meters of 4 inch and 2,000 meters of 3 inch are used the total head loss is 34 meters which is 16 meters less than the available head of 50 meters. A more economical solution would be the use of 1,000 meters each of 4 inch, 3 inch, and 2.5 inch pipe. The total head loss of these three pipes is 44 meters which more closely matches the available head. The HGL is plotted on the figure below.

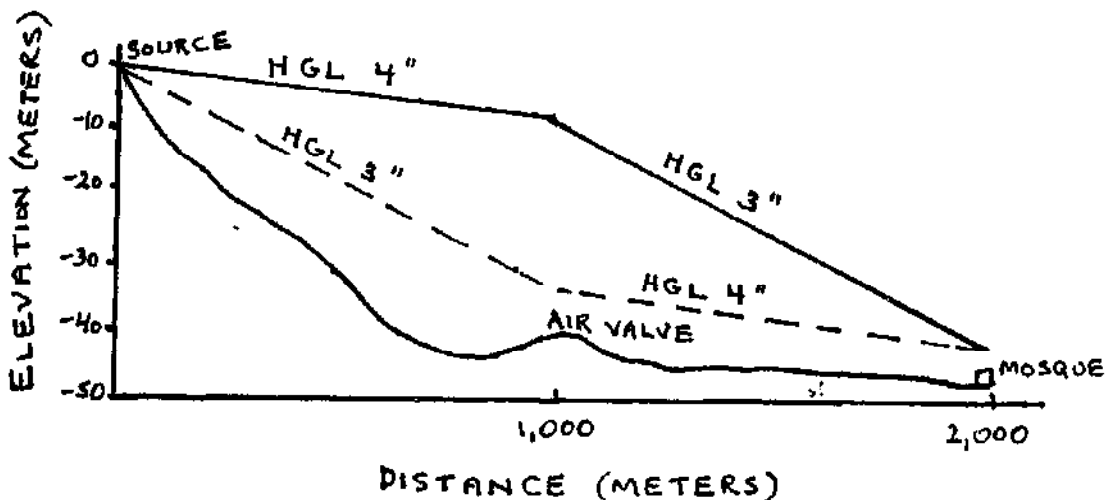


P.17. The figure below contains a ground profile from a water source to a reservoir located at a mosque 2,000 meters from the source. An air valve is located 1,000 meters from the source. The design flow for this section of pipe is 6 l/s. Plot the HGL for 4 inch pipe from the source to the air valve and 3 inch GI pipe from the air valve to the mosque. Now plot the HGL using 3 inch GI pipe from the source to the air valve and 4 inch GI from the air valve to the mosque.



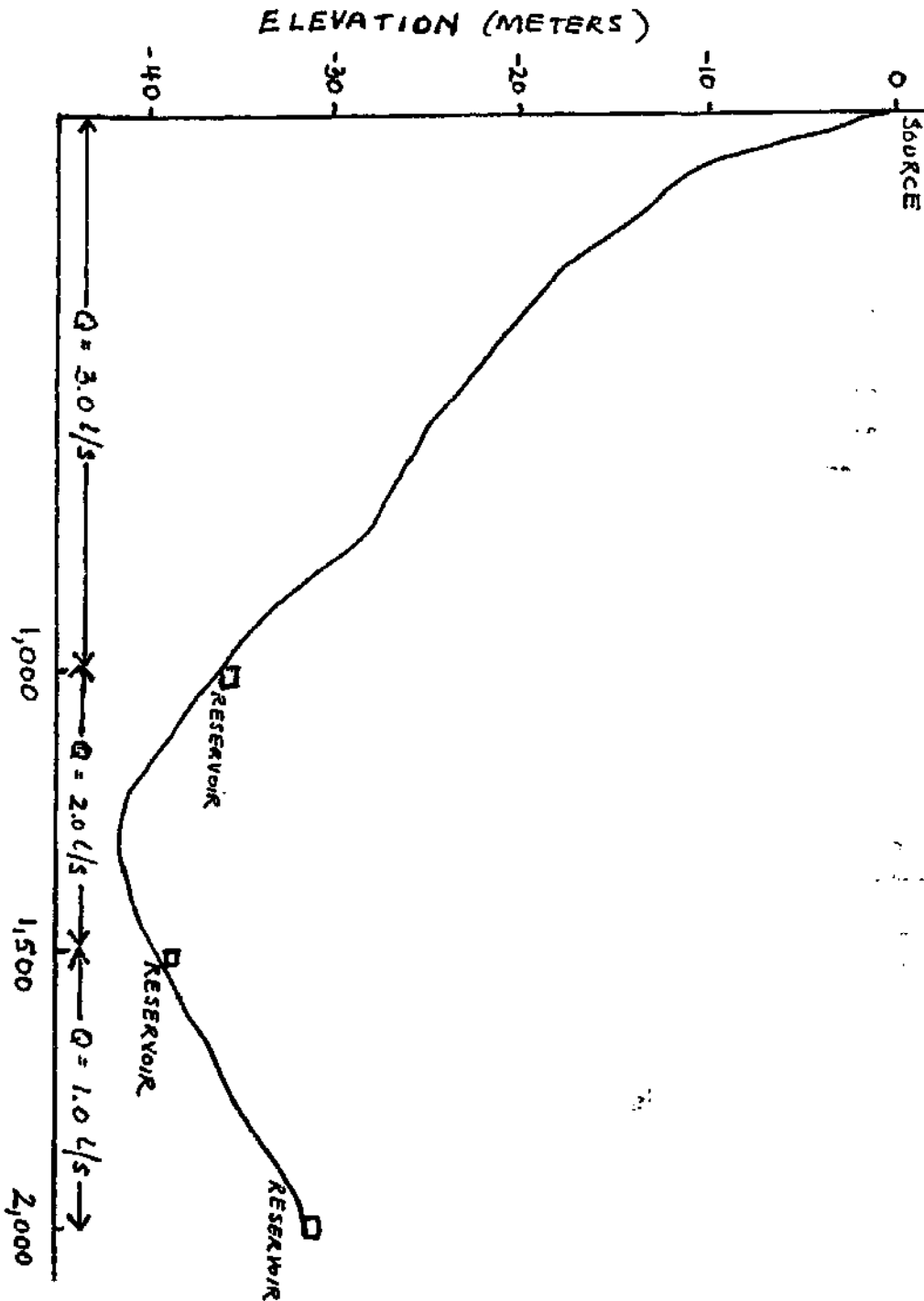
a. Is there any differences between the two configurations ?

S.17. From the water flow calculator the head loss for 1,000 meters of 4 inch GI pipe with a flow of 6 l/s is 8 meters. For 3 inch GI pipe it is 33 meters. The HGLs are plotted on the figure below.

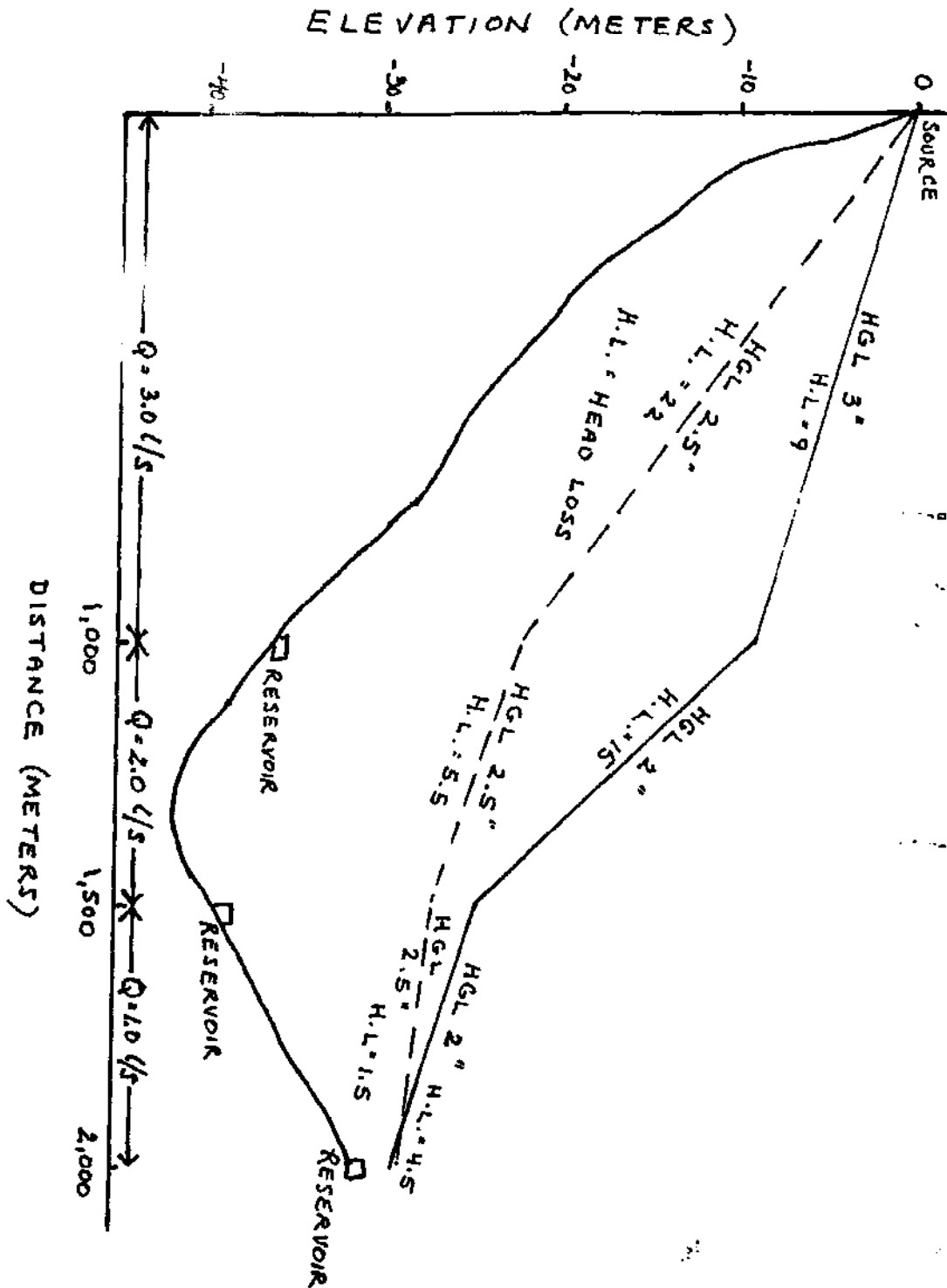


a. Both configurations will result in approximately the same amount of water flowing to the mosque. If the 3 inch pipe is placed first then there is a greater amount of turbulence and a greater head loss at the transition point between the 3 and 4 inch pipes. The flow in the transition area from a 4 inch to a 3 inch pipe is smoother and results in a smaller head loss. However, for this particular situation the effect is negligible.

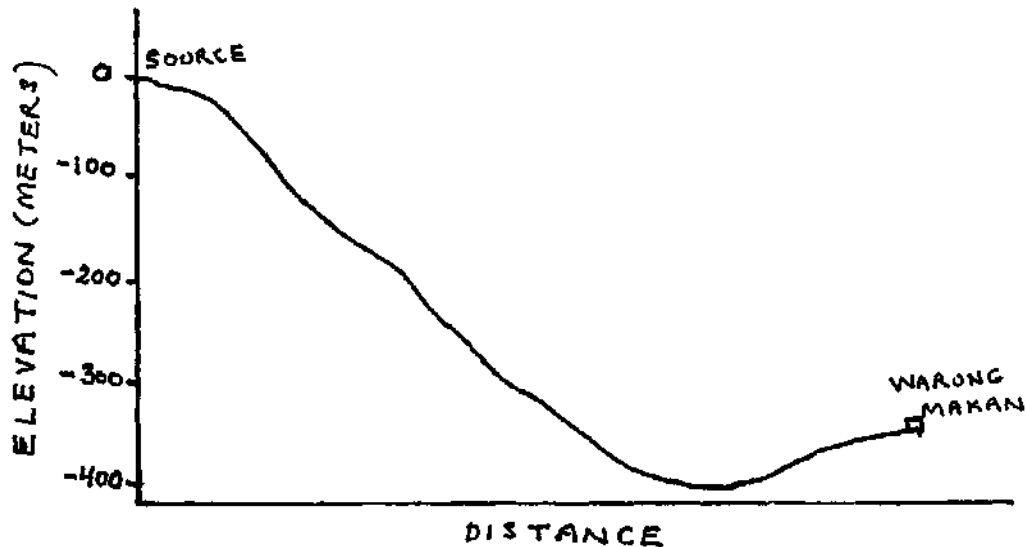
P.18. Given the profile and design flows in the figure below recommend appropriate pipe sizes. Use GI pipe. Suggest two alternatives.



S.18. The HGL and Head Losses are plotted on the figure for two alternatives. Thus, it is acceptable to use either 2,000 meters of 2.5 inch pipe or 1,000 meters each of 3 inch and 2 inch pipe. The head losses for both of these are approximately the same and the flow of water would also be approximately the same.



P.19. Water for a small warung makan is to be provided from a spring in the mountains. Given the ground profile in the figure below recommend possible locations for break pressure tanks. Assume that GI pipe is used.



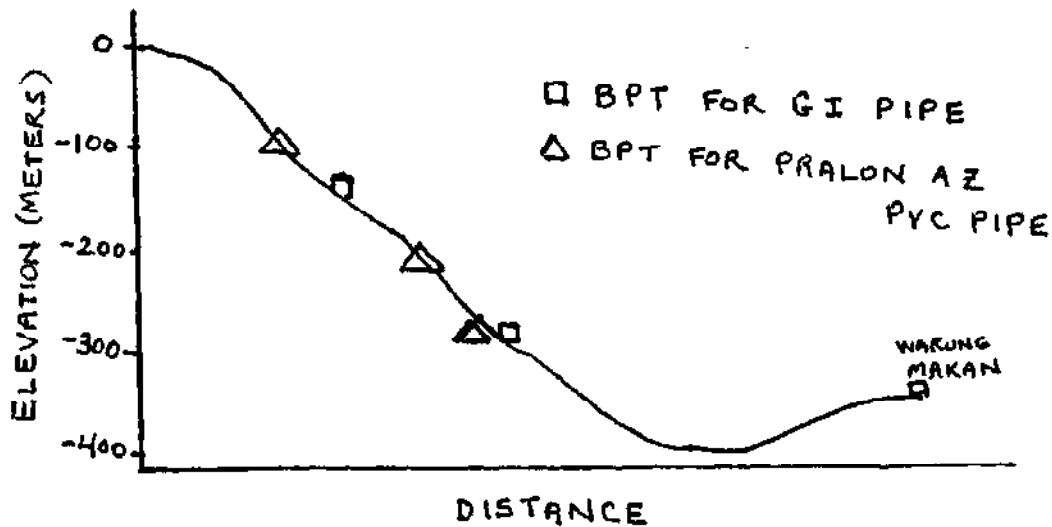
- What is the greatest static pressure that will occur in the pipeline with the suggested placement of break pressure tanks ?
- Will the highest static pressure ever be attained ? What are the reasons ?
- Would the placement of the tanks be different for PVC pipe ? What are the reason ? Recommend possible locations for break pressure tanks if prelon class AZ pipe is used.

S.19. The difference in elevation between the source and the warung makan is 350 meters. The lowest point on the proposed pipeline is 400 meters lower than the source. For GI pipelines with fittings, the maximum recommended head is 50 meters and for lines without fittings, 200 meters.

However, the pipeline has a low point at 400 meters before rising again to 350 meters at the warung makan. In order for water to flow to the warung makan the lowest tank must be above the 350 meter elevation level. It is therefore recommended that the lowest tank be placed at 300 meters so that 50 meters of head be available for the water to flow from that point to the warung makan.

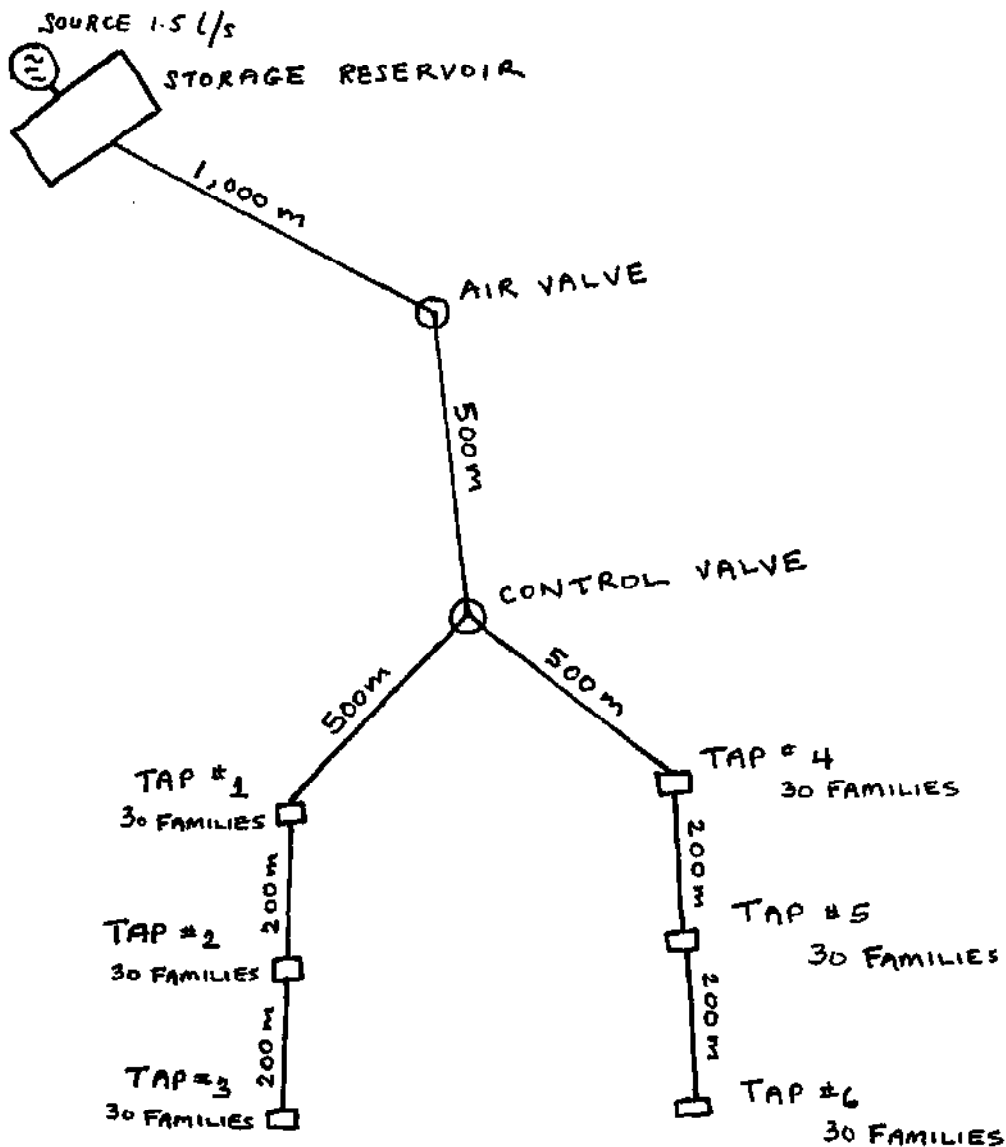
With one tank placed at 300 meters another tank is necessary at an elevation of 150 meters so that the recommended limit of 200 meters is not exceeded.

Suggested locations of the two tanks are noted on the figure below.



- a. With the suggested placement of tanks the greatest static pressure that can be attained is 150 meters.
- b. The highest static pressure of 150 meters will be attained only if the water flow to either of the tanks is stopped and the pipe remains full of water. It is therefore preferable that no valve be placed at the inflow to the tanks so that this situation does not occur.
- c. Because the strength of PVC is different than GI the placement of the tanks would be different and would depend on the class of PVC pipe utilized. Pralon class AZ pipe has a pressure rating of 10 cm^2/kg which is approximately equivalent to 100 meters of head. Thus, the pipeline pressure should never exceed 100 meters. In this case three tanks would be necessary, placed at 100, 200 and 300 meter elevations. These locations are noted on the figure above.

P.20. The Department of Local Transmigration is building a small kampong which will eventually have a population of 900 persons. They are planning to build a small gravity fed water system using a spring above the kampong with an estimated minimum flow of 1.5 l/s. Each person should receive at least 80 liters per day of water which will be distributed to 6 public tap areas. The Figure below is a general sketch of the village and planned distribution system.



P.20.1. In this system a storage reservoir will be constructed at the spring. Recommend an appropriate volume for the reservoir? How was the volume calculated? Suggest approximate dimensions for the reservoir.

P.20.2. There are 6 public tap areas for distributing water. How many faucets should each tap area have?

P.20.3. What is the design flow of water in each section of the distribution system ? How is the flow calculated ?

- a. From the reservoir to the control valve
- b. From the control valve to Tap # 1
- c. From Tap # 1 to Tap # 2
- d. From Tap # 2 to Tap # 3
- e. From the control valve to Tap # 4
- f. From Tap # 4 to Tap # 5
- g. From Tap # 5 to Tap # 6

P.20.4. Differences in elevation are as follows :

- a. Spring to Air valve 50 meters
- b. Air valve to control valve 15 meters
- c. Control valve to Tap # 1 15 meters
- d. Tap # 1 to Tap # 2 5 meters
- e. Tap # 2 to Tap # 3 5 meters
- f. Control valve to Tap # 4 15 meters
- g. Tap # 4 to Tap # 5 5 meters
- h. Tap # 5 to Tap # 6 5 meters

Are any break pressure tanks necessary ? If so, what are their locations ? Assume GI pipe is used.

P.20.5. What pipe sizes are recommended ? Assume that there are no problems with negative pressure. Use GI pipe.

S.20.1. The recommended storage volume for storage at the source is based on the average daily usage and the ratio of the estimated minimum flow to the average daily flow of the source. This system will supply 900 persons with 80 liters/day so the average daily usage is 72 m³ and the average daily flow is 0.83 l/s. The ratio of the estimated minimum flow of the source to the average daily flow is $1.5 \div 0.83$ or 1.8. When the ratio is between one and two then the recommended storage is one half of the average daily use or in this case 36 m³. The inside dimensions of the reservoir could be approximately 5 meters wide by 6 meters long and 1.5 meters deep. The effective depth would be only 1.2 meters if the offtake were placed 15 cm above the floor and the overflow 15 cm below the cover.

- S.20.2. Each tap area serves approximately 150 persons. With four faucets per area there would be 37.5 persons per faucet and this is acceptable.
- S.20.3. The design flows are based on the average daily flow. Since storage is above the point of use the pipe is in use only when the faucets are open. The recommended design flow is thus four times the average daily flow for each section.
- a. From the source to the control valve the average daily flow is 0.83 l/s so the recommended design flow is four times this or 3.32 l/s. In using the water flow calculator this can be rounded up to 3.4 l/s.
- b and e. At the control valve the flow is divided equally to sections b and e so the design flows are one half of 3.4 l/s or 1.7 l/s for these two sections.
- c and f. At taps # 1 and # 4 one third of the flow is utilized and the remaining two thirds is the design flow for the next section of pipe. In this case it is two thirds of 1.7 l/s or 1.13 l/s. This can be rounded up to 1.2 l/s.
- d and g. At taps # 2 and # 5 one half of the remaining flow is utilized and the remainder flows to tap # 3 and # 6. Thus for sections d and g the design flow is one half of 1.2 l/s or 0.6 l/s.
- S.20.4. The total head from the source to the lowest point is 90 meters. Since GI pipe is used it is recommended that the maximum head allowable be 50 meters. Thus a break pressure tank at the air valve is necessary. If the tank is placed at the exact location of the air valve then the air valve is not necessary.
- S.20.5. Using the design flows from paragraph S.20.3., the elevation in paragraph P.20.4., and the water flow calculator the following values are obtained :
- a. From the source to the break pressure tank the distance is 1,000 meters, the design flow 3.4 l/s, and the available head is 50 meters. From the water flow calculator the following values are obtained :

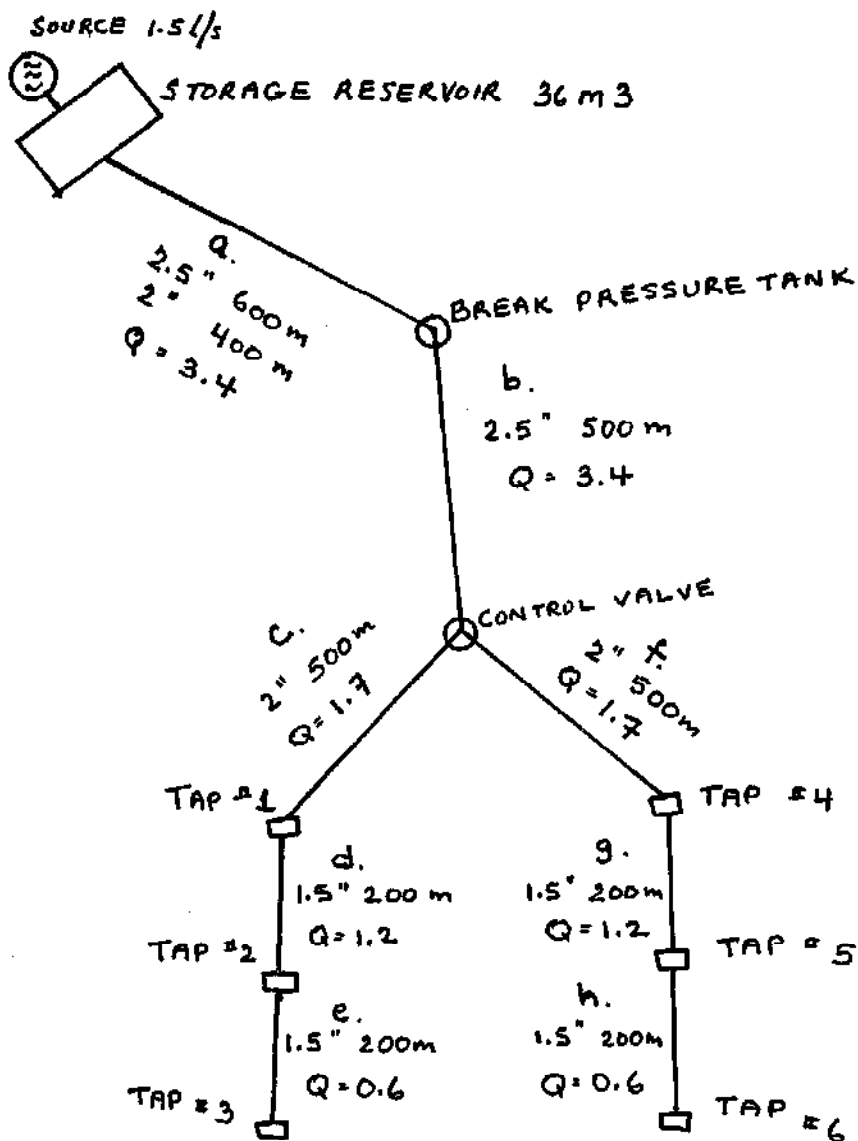
pipe diameter (inches)	length (meters)	head loss (meters) (incl. 10% extra)
3	1,000	13
2.5	1,000	31
2	1,000	90
2.5	600	12
2	400	35

Thus, 600 meters of 2.5 inch and 400 meters of 2 inch pipe with a total head loss of 47 meters is suitable. This solution was found by trial and error.

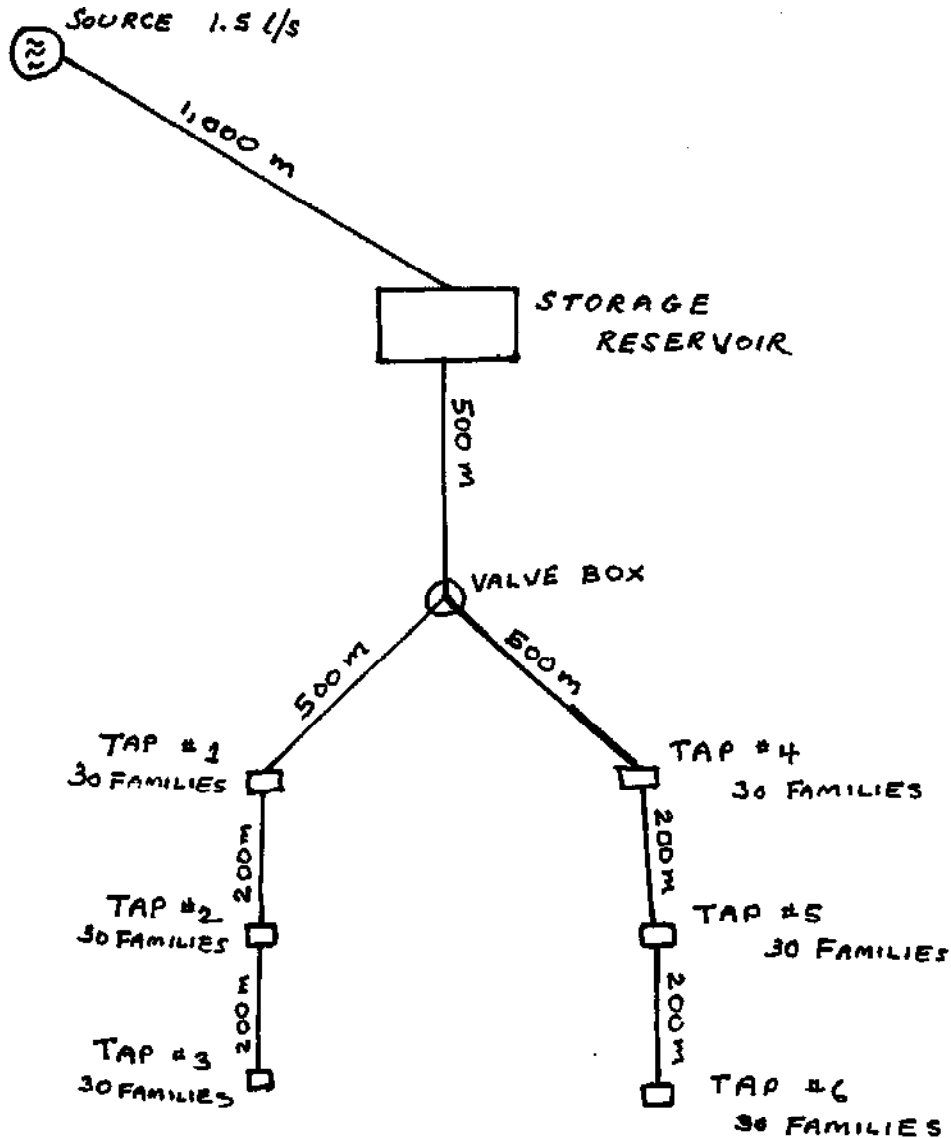
b,c,d,e,f,g,h. For these sections of pipe the following values are obtained from the water flow calculator :

section	length (meters)	flow (l/s)	pipe diameter (inches)	head loss (meters) (incl. 10% extra)
b	500	3.4	3	6
	500	3.4	2.5	11
	500	3.4	2	44
c,f	500	1.7	2.5	4
	500	1.7	2	12
	500	1.7	1.5	52
d,g	200	1.2	2	3
	200	1.2	1.5	11
	200	1.2	1.25	24
e,h	200	0.6	1.5	4
	200	0.6	1.25	7
	200	0.6	1	25

The available head from the break pressure tank to tap area # 3 is 40 meters. It is also 40 meters between the tank and tap area # 6. If 2.5 inch pipe is used for section b, 2 inch for sections c and f, 1.5 inch for sections d and g, and 1.5 inch for sections e and h the total head loss is 38 meters and the required flow of water should be obtained. If the 1.5 inch pipe in sections e and h were reduced to 1.25 inch the total head loss would be 41 meters. The available head is only 40 meters but the calculated head losses include 10% extra for possible error so the required amount of water would probably be obtained if the smaller size pipe were used in this section. However, it is best to provide slightly more water if possible and the 1.5 inch is recommended for this section. The design flows and recommended pipe sizes are included in the figure below.



P.21. The Department of Local Transmigration is building a small kampong which will eventually have a population of 900 persons. They are planning to build a small gravity fed water system using a spring above the kampong with an estimated minimum flow of 1.5 l/s. Each person should receive at least 80 liters per day of water which will be distributed to 6 public tap areas. The figure below is a general sketch of the village and planned distribution system.



P.21.1. In this system a storage reservoir will be constructed 500 meters from the village. Recommend an appropriate volume for the storage reservoir. How was this volume calculated? Suggest approximate dimensions for the reservoir?

P.21.2. There are six public tap areas for distributing water. How many faucets should each public tap area have?

P.21.3. What is the design flow of water in each section of the distribution system ? How is the flow calculated ?

- a. From the Spring to the Storage Reservoir
- b. From the Storage Reservoir to the Valve Box
- c. From the Valve Box to Tap # 1
- d. From Tap # 1 to Tap # 2
- e. From Tap # 2 to Tap # 3
- f. From the Valve Box to Tap # 4
- g. From Tap # 4 to Tap # 5
- h. From Tap # 4 to Tap # 6

P.21.4. Differences in elevation are as follows :

- | | |
|---------------------------|-----------|
| a. Spring to Reservoir | 50 meters |
| b. Reservoir to Valve Box | 15 meters |
| c. Valve Box to Tap # 1 | 15 meters |
| d. Tap # 1 to Tap # 2 | 5 meters |
| e. Tap # 2 to Tap # 3 | 5 meters |
| f. Valve Box to Tap # 4 | 15 meters |
| g. Tap # 4 to Tap # 5 | 5 meters |
| h. Tap # 5 to Tap # 6 | 5 meters |

Assume GI pipe is used. Are any Break Pressure Tanks needed ?
If so what are their locations ?

P.21.5. What pipe sizes are recommended ? Assume that there are no problems with negative pressures. Use GI pipe.

P.21.6. The Department of Village Development wishes to introduce the making of "krupuk Kanji" into this settlement. Could this have any influence on the answers to point 21.1. to 21.5. ? If so, what would be the influence ?

S.21.1. The system supplies 900 persons with 80 liters/day or a total of 72,000 liters/day. The average daily usage is then 72 m³. Since the storage is 1,000 meters below the source the pipe from the source to the reservoir will be in use constantly and the recommended storage is one half of the average daily usage or 36 m³. The inside dimensions of the reservoir could be approximately 5 meters wide by 6 meters long and 1.5 meters deep. The effective depth would be only 1.2 meters if the offtake were placed 15 cm above the floor and the overflow 15 cm below the cover.

S.21.2. Each public tap area serves approximately 150 persons.

If each tap area had 4 faucets then there would be 37.5 persons per faucet and this is acceptable.

S.21.3. The design flows are based on the average daily flow and the placement of storage.

- a. From the spring to the storage reservoir the average daily usage is 72,000 liters or an average daily flow of 0.83 l/s. Since the water is flowing continuously from the source to the reservoir the recommended design flow is 0.83 l/s for this section. In using the water flow calculator this is rounded up to 0.85 l/s.
- b. Below the storage reservoir the water is flowing only when the faucets are in use and therefore the pipe must be of larger capacity. The recommended design flows is then 4 times the average daily flow or $4 \times 0.85 \text{ l/s}$ equal to 3.4 l/s.
- c. At the valve box the flow is divided into two; serving 90 families on each branch. Thus the design flow from the box to Tap #1 is one half of 3.4 or 1.7 l/s.
- d. At Tap # 1 one third of the water flowing from the valve box will be used and the remaining two thirds will flow to Taps # 2 and #3. Thus the design flow for this section is two thirds of 1.7 l/s or 1.13 l/s. This can be rounded up to 1.2 l/s.
- e. At Tap # 2 one half of the flow is utilized and the remainder flows to Tap # 3. Thus the design flow for this section is one half of 1.2 or 0.6 l/s.
- f. This section is the same as c. above or 1.7 l/s.
- g. This section is the same as d. above or 1.2 l/s.
- h. This section is the same as e. above or 0.6 l/s.

S.21.4. The storage Reservoir will act as a break pressure tank with the proposed design. No others are necessary because the maximum head at any point in the system is less than 50 meters.

S.21.5. Using the design flows from paragraph S.21.3., the elevations in paragraph P.21.4., and the water flow calculator we find the following :

a. From the spring to the reservoir is 1,000 meters, the design flow is 0.85 l/s, and the available head is 50 meters. From the water flow calculator the following values are obtained :

pipe diameter (inches)	length (meters)	head loss (meters) (incl. 10% extra)
1.25	1,000	65
1.5	1,000	29
1.25	500	33
1.5	500	15

Thus a combination of 500 meters of 1.5 inch and 500 meters of 1.25 inch pipe with a total head loss of 48 meters is suitable for this section. This solution was found by trial and error.

b. From the storage reservoir to the valve box is 500 meters, the available head is 15 meters, and the design flow is 3.4 l/s. From the water flow calculator the following values are obtained :

pipe diameter (inches)	length (meters)	head loss (meters)
3	500	6
2.5	500	11
2	500	44

Thus a 2.5 inch pipe with a head loss of 11 meters is suitable.

c,d, & e.

For these sections of the distribution system the following head losses are obtained from the water flow calculator.

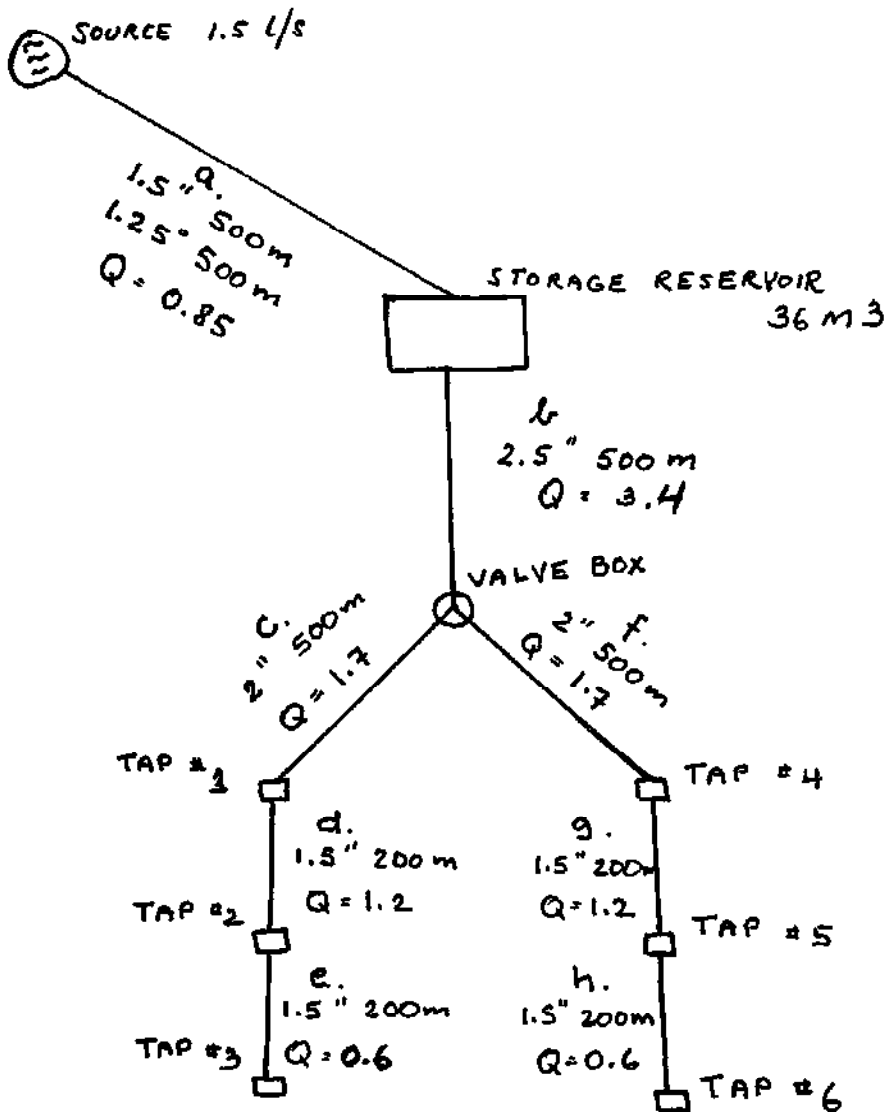
Section	length (meters)	flow (l/s)	pipe diameter (inches)	head loss (meters) (incl. 10% extra)
c	500	1.7	2.5	4
	500	1.7	2	12
d	200	1.2	2	3
	200	1.2	1.5	11
e	200	0.6	1.5	3
	200	0.6	1.25	7

For sections c,d, and e the total available head is 25 meters. If section c were 2 inch, section d 1.5 inch, and section e 1.5 inch the total head loss would be 25 meters and these pipe sizes are appropriate.

f,g, and h.

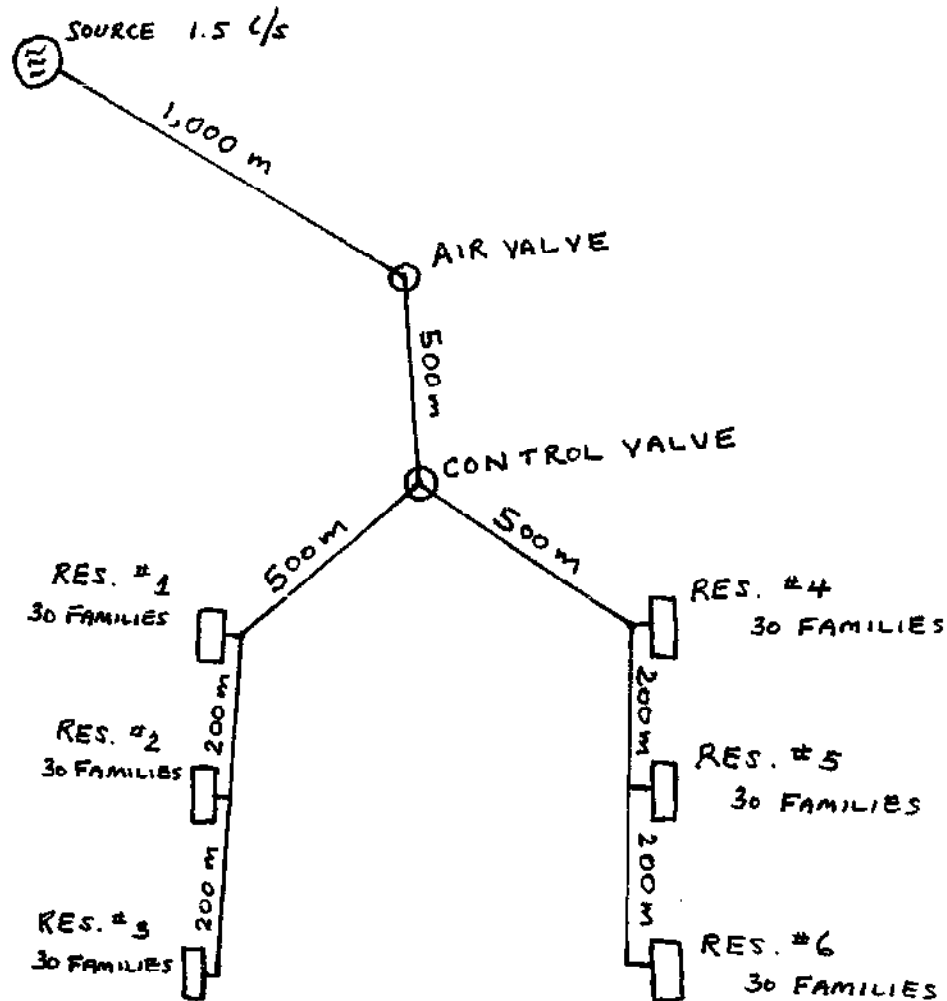
These sections are identical to c,d, and e.

The design flows and recommended pipe sizes are included on the figure below.



S.21.6. The manufacture of "krupuk kanji" requires the use of water and the design flows should be increased to supply the necessary amount. For example two small processing areas could be located near taps # 1 and # 4. If each area were supplied with 0.2 l/s (or 17.2 m³/day) then the design flow for sections a and b would be increased by 0.4 l/s and the design flows for sections c and f by 0.2 l/s.

P.22. The Department of Local Transmigration is building a small kampong which will eventually have a population of 900 persons. They are planning to build a small gravity fed water system using a spring above the kampong with an estimated minimum flow of 1.5 l/s. Each person should receive at least 80 liters per day of water which will be distributed to 6 public reservoirs. The Figure below is a general sketch of the village and planned distribution system.



P.22.1. In this system six small reservoirs will be built in the kampong. Recommend an appropriate volume for the storage reservoir. How was this volume calculated? Suggest approximate dimension for the reservoirs.

P.22.2. How many faucets should each of the six reservoirs have?

- P.22.3. What is the design flow of water in each section of the distribution system? How is the flow calculated?
- From the spring to the control valve
 - From the control valve to Reservoir # 1
 - From Reservoir # 1 to Reservoir # 2
 - From Reservoir # 2 to Reservoir # 3
 - From the control valve to Reservoir # 4
 - From Reservoir # 4 to Reservoir # 5
 - From Reservoir # 5 to Reservoir # 6

P.22.4. Differences in elevation are as follows :

- | | |
|-------------------------------|-----------|
| a. Spring to Air valve | 50 meters |
| b. Air valve to Control Valve | 15 meters |
| c. Control Valve to Res # 1 | 15 meters |
| d. Res # 1 to Res # 2 | 5 meters |
| e. Res # 2 to Res # 3 | 5 meters |
| f. Control Valve to Res. # 4 | 15 meters |
| g. Res # 4 to Res # 5 | 5 meters |
| h. Res # 5 to Res # 6 | 5 meters |

Assume GI pipe is used. Are break pressure tanks needed?

If so, what are their locations?

P.22.5. What pipe sizes are recommended? Assume that there are no problems with negative pressures. Use GI pipe.

S.22.1. The system supplies 900 persons with 80 liters/day or a total of 72,000 liters/day. The average daily usage is then 72 m³. Since storage is at the point of use the recommended amount is one half of the average daily usage or 36 m³. Since the population is spread evenly among the six reservoirs they can each be 6 m³. Appropriate inside dimensions of the reservoir would be 4 meters long by 1.5 meters wide and 1.2 meters deep. The offtake would be placed 10 cm above the floor and the overflow 10 cm below the cover so the effective depth would be one meter.

S.22.2. Each reservoir serves approximately 150 persons. With 4 faucets per reservoir there would be 37.5 persons per faucet and this is acceptable.

S.22.3. The design flows are based on the average daily flow as follows :

- From the spring to the control valve the average daily usage is 72,000 liters equal to an average daily flow of 0.83 l/s. The recommended design flow is then 0.83 l/s. In using the water flow calculator this can be rounded up to 0.85 l/s.

- b. At the control valve the flow is divided equally and 0.425 l/s is the design flow from the control valve to the reservoir # 1. This can be rounded up to 0.43 l/s.
- c. The usage is the same at each reservoir so one third of the flow will enter reservoir # 1 and the remaining two thirds will flow to reservoirs # 2 and # 3. Thus, the design flow for the section between reservoirs # 1 and # 2 is two thirds of 0.43 l/s or 0.287 l/s. In using the water flow calculator this can be rounded up to 0.3 l/s.
- d. At reservoir # 2 one half of the remaining flow enters the reservoir and the remainder flows to reservoir # 3. Thus, the design flow is one half of 0.30 l/s or 0.15 l/s.
- e. This is the same as b. above.
- f. This is the same as c. above
- g. This is the same as d. above

S.22.4. The total head from the source to the lowest point is 90 meters. Since GI pipe is used it is recommended that the maximum head allowable be 50 meters. Thus a break pressure tank at the air valve is necessary. If the tank is placed at the exact location of the air valve then the air valve will not be necessary.

S.22.5. Using the design flows from paragraph S.22.3., the elevations in paragraph P.22.4., and the water flow calculator, the following values are obtained :

- a. From the source to the break pressure tank the distance is 1,000 meters, the design flow 0.85 l/s, and the available head is 50 meters. From the water flow calculator the following values are obtained :

pipe diameter (inches)	length (meters)	head loss (meters) (incl. 10% extra)
1.25	1,000	65
1.5	1,000	29
1.25	500	33
1.5	500	15

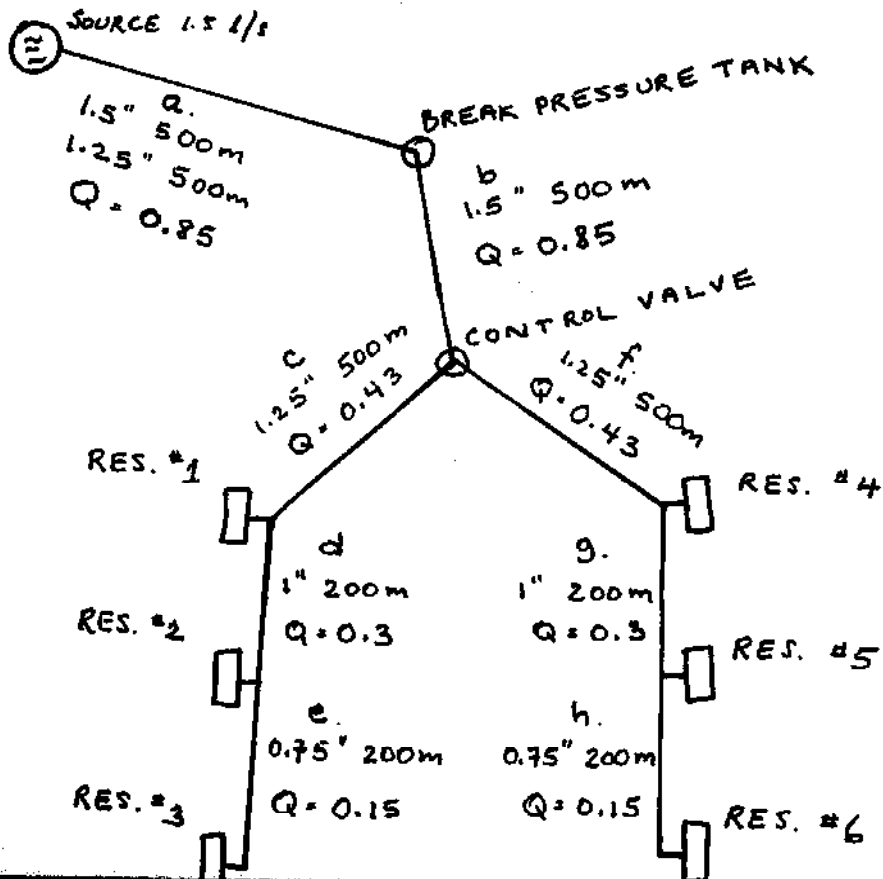
Thus a combination of 500 meters of 1.5 inch and 500 meters of 1.25 inch pipe with a total head loss of 48 meters is suitable for this section. This solution was found by trial and error.

b,c,d,e,f, and h.

For these sections of pipe the following values are obtained from the water flow calculator :

Section	length (meters)	flow (l/s)	pipe diameter (inches)	head loss (meters) (incl.10% extra)
b	500	0.85	2	4
	500	0.85	1.5	14
	500	0.85	1.25	33
c,f	500	0.43	1.5	5
	500	0.43	1.25	10
		0.43	1	33
d,g	200	0.3	1.25	2
	200	0.3	1	7
	100	0.3	0.75	26
e,h	200	0.15	1	2
	200	0.15	0.75	8
	200	0.15	1.25	1

The total head loss from the break pressure tank to reservoir # 3 is 40 meters. It is also 40 meters between the tank and the reservoir # 6. If 1.5 inch pipe is used for section b, 1.25 inch for sections c and f, 1 inch for sections d and g, and 0.75 inch for sections e and h the total head loss is 39 meters. Thus, the required flow of water should be obtained with these pipe sizes. The design flows and recommended pipe sizes are included on the figure below.



P.23. Make a rough cost estimate for the three water systems of P.20., P.21., and P.22. Use the following information :

- a. The cost of the spring protection is Rp. 500,000
- b. The cost of pipe installation is Rp. 1,500,000 for each system
- c. The cost of pipe per 6 meter length is as follows :
 - 2.5 inch Rp. 17,250
 - 2 inch Rp. 12,250
 - 1.5 inch Rp. 9,450
 - 1.25 inch Rp. 7,800
 - 1.0 inch Rp. 6,250
 - 0.75 inch Rp. 4,250
- d. The cost of a 6 m³ reservoir is Rp. 450,000
The cost of a 36 m³ reservoir is Rp. 1,300,000
- e. The cost of a public tap area is Rp. 50,000
- f. The cost of a 1 m³ BPT is Rp. 100,000
- g. The cost of extra fittings is Rp. 500,000 for each system

S.23. Estimated Cost for System in P.20.

a. Spring Protection	Rp. 500,000
b. Pipe Installation	Rp. 1,500,000
c. Pipe	Rp. 7,300,000
d. Storage Reservoirs	Rp. 1,500,000
e. Public Tap Areas	Rp. 300,000
f. BPT	Rp. 100,000
g. Extra Fittings	Rp. 500,000

T o t a l Rp.11,700,000

=====

Estimated Cost for System in P.21.

a. Spring Protection	Rp. 500,000
b. Pipe Installation	Rp. 1,500,000
c. Pipe	Rp. 6,200,000
d. Storage reservoirs	Rp. 1,500,000
e. Public Tap Areas	Rp. 300,000
f. BPT costs	-
g. Extra Fittings	Rp. 500,000

T o t a l Rp.10,500,000

=====

Estimated Cost for System in P.22.

a. Spring Protection	Rp. 500,000
b. Pipe Installation	Rp. 1,500,000
c. Pipe	Rp. 4,100,000
d. Storage Reservoirs	Rp. 2,700,000
e. Public Tap Areas	-
f. BPT	Rp. 100,000
g. Extra Fittings	Rp. 500,000

T o t a l Rp. 9,400,000

The least expensive option is the use of small storage reservoirs at the point of use. If the estimated minimum flow of the source were greater than 3.4 l/s, which is the estimated peak usage, then the 36 m³ storage reservoir in the system in P.20. could be eliminated. This would save Rp. 1,500,000 and the estimated cost would be comparable to the use of small reservoirs at the point of use. However, small reservoirs would still be the preferred type of design because they would increase water usage, promote more efficient use and equitable distribution of the water, and reduce problems with the faucets.