SOPAC Water Resources Unit

Calibration of TWB Water Reticulation Model

Attachment to the SOPAC Secretariat from 2 – 27 August 1999

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and

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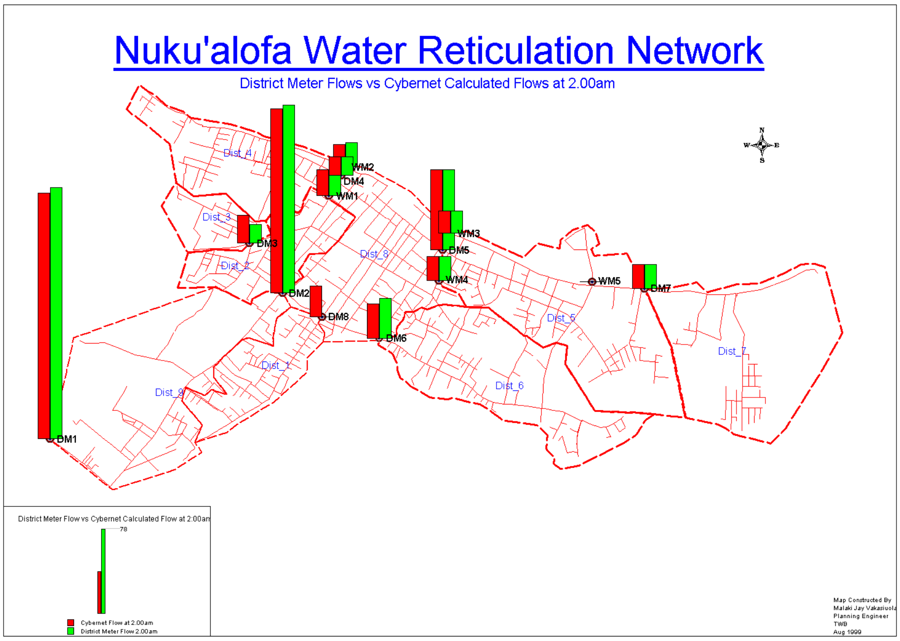

September 1999 **SOPAC Miscellaneous Report 350**

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Foreword

This report is the outcome of an attachment of Mr. Malakai Vakasiuola, Tonga Water Board (TWB) Planning Engineer, to SOPAC Water Resources Unit. The objective of the attachment was to produce a calibrated numerical model for the Nuku'alofa water supply system and test a proposed upgrading project.

I first met Malakai in November 1998 when we started to develop such a model but could only produce an uncalibrated model due to the short amount of time we had available (less than 1 week). As a result we developed the idea for an attachment to the SOPAC Secretariat in order to have the necessary time and resources to concentrate on this particular task. Due to many reasons it did not eventuate before August 1999.

The following report has been written by Malakai and I'm happy that I had the chance to co-author it. After some thinking about editing and formalising the report, I came to the conclusion that it would be best if the 'original spirit' of the report would be preserved: After all it is his work and he's written it in his particular style for his people. I guess the chances that it will be looked into and read increases proportionally with the reasonable volume of it and the right choice of words. Hence, I limited editing and comments to what I thought was necessary for clarification and enhanced background. This background information has been added to the report in the form of footnotes. I further included some pictures and tables into the report text rather than presenting them as Annexes only. That should make reading more enjoyable.

However, the outcome is not limited to this report. All data is available in electronic form and has been condensed on a CD including a Geographical Information System (GIS), the Numerical Model and all spreadsheets produced throughout the attachment.

The Co-Author

Harald Schölzel

Introduction

TWB had set up a Master Plan to Upgrade the existing water reticulation network. PPK Consultant, a private consultant was hired to write up a master plan in 1992 (PKK, 1992). The master plan was drawn and the TWB then set out to find a donor to finance the upgrade proposal. The Japanese Government was approached to fund the proposed upgrade. Before the Japanese Team arrived, TWB was asked to see if the Master Plan, which was drawn up in 1989, was still valid. The Master Plan had a computerised model done on Watsys[1], a DOS program. The program was very complicated, not only that, it had not been used before at TWB.

In November 1998, the SOPAC Water Resources Unit provided assistance to TWB addressing problems TWB had with detecting PVC pipes (SOPAC, 1998). The objective of this mission was extended to look into the Master Plan solution to support the upgrading project. Together with support from SOPAC a new hydraulic network model was developed using what was perceived to be a more appropriate and modern software package (SOPAC, 1999). At the same time SOPAC offered more targeted assistance with the use of Geographical Information Systems (GIS) and Hydraulic Network Models to TWB. An attachment was seen as the best way to provide this very specialised training and a four weeks attachment of the TWB Design and Planning Engineer was scheduled.

This report summarises the work during this attachment from 2 to 27 of August 199 and its results.

[1] *The reader should also notice that WATSYS, Cybernet, MapInfo, MS Excel and MS Access are commercial software packages and registered trademarks i.e. all copyrights apply.*

Acknowledgement

The attachment and this report were only possible with the strong support from the Tonga Water Board, namely, Saimone P. Helu, General Manager and Lesieli Niu, Acting Chief Engineer. The authors also wish to thank Graham White, Team Leader of the AusAID funded Institutional Strengthening Project for providing the funds for the airfare from Tonga to Fiji.

The remainder of the attachment costs were covered by the SOPAC Human Resources Development Unit.

Previous Work

The TWB assets were drawn on MapInfo. Using this as a DXF base, the pipes were than drawn on top of the DXF background. The pipe type and diameter were also entered. The Reservoir, its elevation, both node and tank were entered as well. There is one booster pump and this was entered as well. The elevation was based on a 5-meter contour drawn up by the MLSNR, which gave us a rough estimate of elevation. What was really needed was 1 meter contour or less to provide a more accurate reading of the pressure head to compare with the actual pressure reading which was measured manually by the TWB engineering staff, once calculation had been performed.

The Base Demand and Demand Pattern were taken from the Master Plan, which was done by PPK Consultants. The PPK Demand and Demand Pattern was based on a demand pattern of a town similar to the size of Nuku’alofa, which they took as Suva. This pattern was used to run the Watsys model and later used on this Cybernet model. The TWB Master Plan model was then run on Cybernet and proved that the Master Plan was still valid even though higher than originally suggested demands were imposed on the model (SOPAC, 1999b)

The model of the existing network was completed and was ready to run. Instead of calculating for the Pressure Head, the HGL was used instead of pressure because the elevation of the junction wasn’t known exactly yet. The model was than color-coded so if the HGL of a junction is less than or equal to zero the junction would come out red. When the model ran, it showed that the imposed demand could not be satisfied at any junction during maximum demand at peak hour (7:00 AM)[2]. This showed that the network was not able to supply enough water to its customers, which was what the TWB is currently facing. The one thing that was needed to be done to the model was to get it calibrated to yield more accurate output to match the manual reading.

Even though it was not the exact figures as the manual reading it provided something of a guideline and clearly showed the value of the proposed Master Plan solution of Nuku'alofa's water supply problems.

[2] *Existing modeling software display these relation computing negative pressure for those junctions where water flow is too high resulting in friction losses too high. Since there is no negative pressure in this world it indicates exactly the described inability to supply the imposed demand (flow). This relation is of paramount importance for hydraulic network modelers.*

Calibration of the Model

The results of the previous model clearly showed that there was a need to have the model further calibrated to give more accurate calculations compared with the measured readings of pressure and flow within the real system. The time between the development of the first model in November 1998 and the attachment to SOPAC in August 1999 was used to collect the minimum of data needed to generate and calibrate a hydraulic network model for the Nuku'alofa water supply system.

Data Processing

The first thing needed to be done was to download and sort the data that had been collected. The data both came on hard copy and on MapInfo tables. The coordinates of the junctions[3] were then imported from Cybernet into MapInfo[4]. This enables MapInfo to create points for the junctions. The other tables that were constructed were the Billing Blocks and District, which was the area that each district meter served.

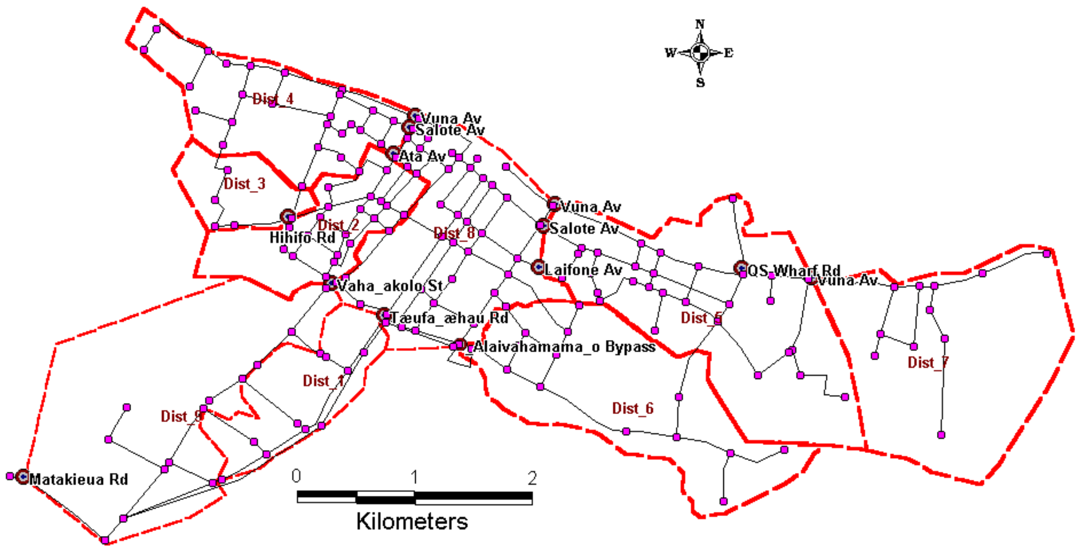

Figure 1: Districts and district meters of the Nuku'alofa water supply system

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[3] 'Junctions' or 'Nodes' join pipes in a network model. They hold demand information and are the points where results such as Hydraulic Grade Line (HGL) or Pressure are displayed. Junctions are joined by pipes that hold information on the headloss and the flow rates etc.

[4] This is possible only if special database connections have been set up. It involves also the setup of a database server file such as MS Access. After a rather complicated process the exchange of information between CyberNet and MapInfo works on a button-click enabling the user to use eg MapInfo to evaluate complicated contour maps or census information and pass it on to CyberNet where it will be used for computing and then returned.

The Billing block was the serviced area divided into 19 blocks to make it easier for the meter readers to read different blocks. The District also was the service area divided into 9 Districts each with District Meter to measure flows of each district. This is an excellent method to be able to work out where there is possibility of leakage along the mains.

Using the Billing Block as a Guideline.

The first approach was to use the billing block information to see which junctions were contained in which billing block and therefore assign the usage of that block and distributed evenly into those junction. Running a query on MapInfo did this.

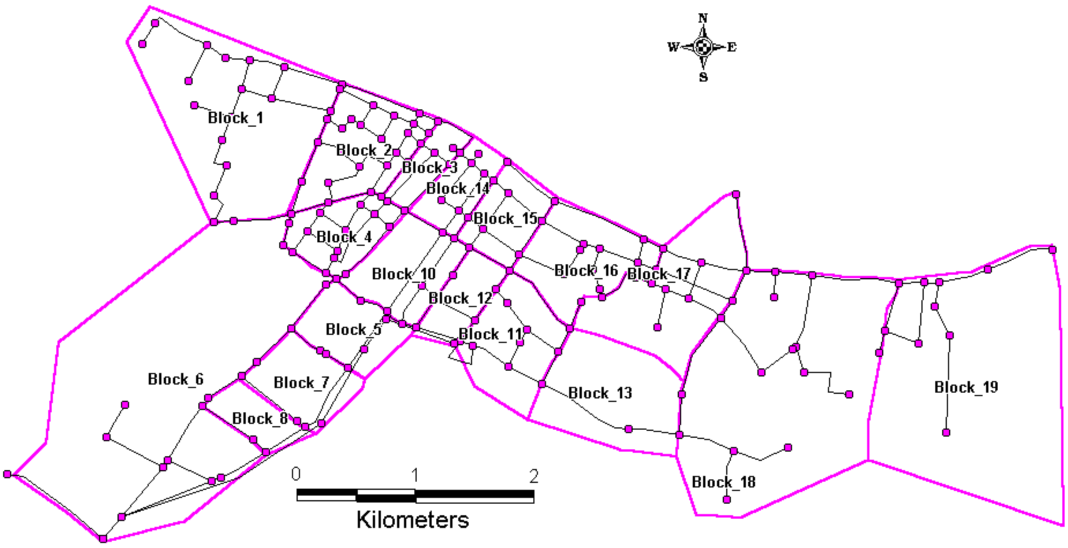


Figure 2: Billing blocks for Nuku'alofa water supply system

The problem faced was that the billing reading were divided into 3 categories which was Government, Commercial and Domestic usage. This proved to be rather difficult to enter into CyberNet and it was then decided to add the Government and Commercial together because there was not much difference in the behavior of their usage pattern. This left only 2 demand categories, Commercial and Domestic.

Table 1: Billing block information by population, connections and end use

R/SEQ	COM	DOM	GOVT	TOT CONN	COM USAGE	DOM USAGE	GOVT USAGE	TOT USAGE
1	6	467	9	482	52,866	4,131,233	79,299	4,263,398
2	7	392	1	400	74,176	4,153,837	10,597	4,238,610
3	1	113	0	114	13,759	1,549,799	0	1,563,558
4	3	309	2	314	34,340	3,519,899	22,894	3,577,133
5	10	98	10	118	322,925	3,166,722	322,925	3,812,572
6	45	783	6	834	858,814	16,058,456	122,688	17,039,958
7	6	368	0	374	44,462	4,150,045	0	4,194,507
8	3	179	0	182	28,548	1,701,642	0	1,730,190
10	43	177	30	250	62,780	5,100,410	704,071	5,867,261
11	8	224	0	232	118,478	3,315,663	0	3,434,141
12	14	386	0	400	131,350	4,175,203	0	4,306,553
13	10	212	0	222	115,213	2,729,560	0	2,844,773
14	81	98	18	197	2,167,404	2,621,758	481,762	5,270,924
15	83	88	34	205	3,140,202	3,330,258	1,286,955	7,757,415
16	37	367	4	408	590,611	4,485,981	50,243	5,126,835
17	43	423	10	476	592,602	5,838,078	131,908	6,562,588
18	136	400	6	542	1,548,145	4,362,901	66,349	5,977,395
19	5	223	1	229	18,166	811,451	3,666	833,283
	541	5,307	131	5,979	9,914,841	75,202,896	3,283,357	88,401,094

The sum of the consumption of these two categories were than deducted from the total production through the Bulk Meter and therefore used as the unaccounted-for-water. This was then classified as leakage which was about 47% of total production.

A spreadsheet on MS Excel was set up to calculate the consumption per block and the number of junctions within that billing block. The consumption was than divided equally into each junction therefore allocating a demand. The unaccounted-for-water was then divided equally into each junction. This was then entered into the Junction Base table on MapInfo and later, to be exported into Cybernet via a MS Access database link. This proved to be more difficult than expected because Cybernet does not allow multiple demand on the global table[5].

[5] *Cybernet has a very comfortable function that allows global editing of multiple network elements. It also allows each junction to have multiple demands and demand patterns each. However, the database connectivity does not allow the specific addressing of these multiple demands on each junction thus severely crippling this function with respect to use GIS to compute demands. This is clearly a major setback.*

Table 2: Breakdown of billing information on a monthly scale

Demand								
Calcualtion	Yearly Cons. m3/yr	Monthly Cons. m3/mth	No Connec.	Pop Served	Cons. m3/mth	Cons. m3/day	Cons. % %	Unit Cons. l/cap/d
Domestic	805541.00	67128.42	5307.00	29170.00	67128.42	2237.61	74.84	76.71
Public	109786.00	9148.83	131.00		9148.83	304.96	10.20	7.67
Commercial	160996.00	13416.33	541.00		13416.33	447.21	14.96	11.51
Total	1076323.00	89693.58	5979.00	29170.00	89693.58	2989.79	100.00	95.89

Table 3: Billing information by block number

	Com Usage	Dom Usage	No Junction			Com	Dom	Com	Dom.
Block No.r	l	l		per day	per day	per jun/day	per jun/day	jun/l/s	jun/l/s
1	132165.00	4131233.00	21	4405.50	137707.77	209.79	6557.51	0.00	0.08
2	84773.00	4153837.00	22	2825.77	138461.23	128.44	6293.69	0.00	0.07
3	13759.00	1549799.00	5	458.63	51659.97	91.73	10331.99	0.00	0.12
4	57234.00	3519899.00	16	1907.80	117329.97	119.24	7333.12	0.00	0.08
5	645850.00	3166722.00	2	21528.33	105557.40	10764.17	52778.70	0.12	0.61
6	981502.00	16058456.00	16	32716.73	535281.87	2044.80	33455.12	0.02	0.39
7	44462.00	4150045.00	2	1482.07	138334.83	741.03	69167.42	0.01	0.80
8	28548.00	1701642.00	2	951.60	56721.40	475.80	28360.70	0.01	0.33
10	766851.00	5100410.00	7	25561.70	170013.67	3651.67	24287.67	0.04	0.28
11	118478.00	3315663.00	9	3949.27	110522.10	438.81	12280.23	0.01	0.14
12	131350.00	4175203.00	3	4378.33	139173.43	1459.44	46391.14	0.02	0.54
13	115213.00	2729560.00	2	3840.43	90985.33	1920.22	45492.67	0.02	0.53
14	2649166.00	2621758.00	8	88305.53	87391.93	11038.19	10923.99	0.13	0.13
15	4427157.00	3330258.00	5	147571.90	111008.60	29514.38	22201.72	0.34	0.26
16	640854.00	4485981.00	10	21361.80	149532.70	2136.18	14953.27	0.02	0.17
17	724510.00	5838078.00	8	24150.33	194602.60	3018.79	24325.33	0.03	0.28
18	1614494.00	4362901.00	16	53816.47	145430.03	3363.53	9089.38	0.04	0.11
19	21832.00	811451.00	9	727.73	27048.37	80.86	3005.37	0.00	0.03
	13198198.00	75202896.00	163	439939.93	2506763.20	71197.06	427229.02	0.82	4.94
	88401.09							71197.06	427229.02

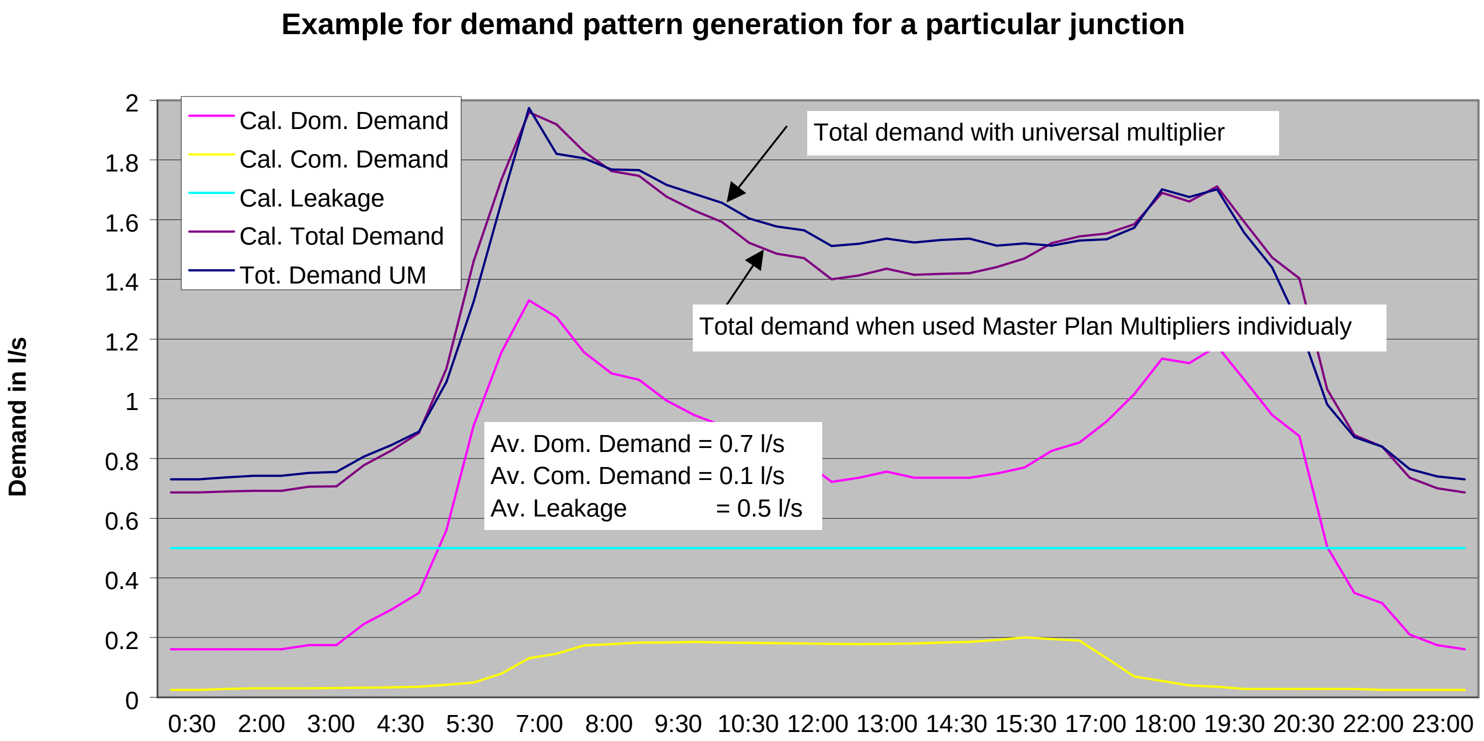
For instance, three different demands for each category. The only way you could do this was to manually enter the three demands into each junction (all in all 163), which would be a long process. Not only that, when you have the junctions show up on a tabular form, it would show up as a composite demand (the total of the 3 demand pattern) and you could not edit it globally but had to do it junction by junction. Heastead Methods, the company who designed Cybernet was contacted to tell if there were any way this problem could be solved. They replied that there was no way to tackle this problem.

Table 4: Breakdown of how assumed demand has been allocated to junctions in the model

Block No.r	No of Junc	Com. Demand	Dom. Demand	Assumed Leakage	Tot. Demand	Total/Junc
	l/s	l/s	l/s	l/s	l/s	l/s
1	21.00	0.00	0.08	0.33	0.40	8.50
2	22.00	0.00	0.07	0.33	0.40	8.84
3	5.00	0.00	0.12	0.31	0.43	2.13
4	16.00	0.00	0.08	0.32	0.41	6.50
5	2.00	0.12	0.61	0.30	1.04	2.08
6	16.00	0.02	0.39	0.32	0.73	11.69
7	4.00	0.01	0.80	0.30	1.11	4.44
8	2.00	0.01	0.33	0.30	0.64	1.27
10	7.00	0.04	0.28	0.31	0.63	4.42
11	9.00	0.01	0.14	0.31	0.46	4.13
12	3.00	0.02	0.54	0.30	0.86	2.57
13	3.00	0.02	0.53	0.30	0.85	2.55
14	8.00	0.13	0.13	0.31	0.56	4.51
15	5.00	0.34	0.26	0.31	0.90	4.52
16	10.00	0.02	0.17	0.31	0.51	5.10
17	8.00	0.03	0.28	0.31	0.63	5.01
18	16.00	0.04	0.11	0.32	0.46	7.43
19	9.00	0.00	0.03	0.31	0.35	3.12
	163.00	0.82	4.94	5.60	11.37	88.81

So we set out to tackle this problem and after some further discussion, after all this is what engineering is all about, we decided to take an average of each demand and use only one demand and design one demand pattern that would fit all three demand patterns put together. This sounded like a reasonable idea but how were we going to calculate a pattern that would fit all three categories? Also, how were we going to calculate the averages of the multipliers for each category and how accurate would our averages be?

We then came up with the idea of a variance table. Therefore, we could work the variance of the different average and if it was too high or low, pick the most reasonable average. A table was then set up on MS Excel to calculate the variance depending on what the average would be. The averages were calculated on the proportion of the each category against the total usage. After calculating the variance using the variance table, an average value was then assigned to each category according to the variance table. This was then plotted against the original demand pattern and after discussion we both agreed that we should try it out. The combined demand was then entered in Cybernet via the MS Access link and the new demand pattern was then used.



	0:30	2:00	3:00	4:30	5:30	7:00	8:00	9:30	10:30	12:00	13:00	14:30	15:30	17:00	18:00	19:30	20:30	22:00	23:00
Cal. Dom. Demand	0.161	0.161	0.175	0.294	0.56	1.33	1.155	0.994	0.91	0.791	0.735	0.735	0.749	0.854	1.015	1.176	0.945	0.35	0.21
Cal. Com. Demand	0.025	0.03	0.03	0.033	0.042	0.13	0.173	0.183	0.183	0.18	0.178	0.183	0.192	0.19	0.07	0.035	0.028	0.028	0.025
Cal. Leakage	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Cal. Total Demand	0.686	0.691	0.705	0.827	1.102	1.96	1.828	1.677	1.593	1.471	1.413	1.418	1.441	1.544	1.585	1.711	1.473	0.878	0.735
Tot. Demand UM	0.730	0.742	0.752	0.844	1.056	1.974	1.805	1.716	1.656	1.564	1.519	1.532	1.513	1.530	1.573	1.701	1.440	0.872	0.765

Figure 3: Example that shows the effect of using a 'universal multiplier' to calculate total demand for a junction

Results

The result computed by applying the above described method to calculate demand patterns and total demands for each junction, respectively, did not resemble the correct pattern that the network actually ran as recorded by a bulk meter at the Matakieua tanks. The demand followed an ideal demand pattern but that was not the case that TWB was running. With low-pressure areas getting water only during off-peak time this offset the demand pattern. A good example is that the difference between the Peak Flow, 97 l/s and Minimum Night flow, 77 l/s (at around 4 am) was only 19.3 l/s. This was partly due to the disappointing condition of not having water supply 24 hours for all areas. However, it seems very likely that the biggest contribution to this irregularity is the high amount of leakage in the water supply system. After some discussion it was agreed to employ the billing block usage but using the district meter as a control.

The district meter readings were now used and followed a similar process as has been used with the billing blocks. The bulk meter reading at Matakieua was then traced onto graph paper, making it possible to calculate a 24-hour period flow, and that was used as a demand pattern. The average daily flow was then calculated with multipliers to go with it.

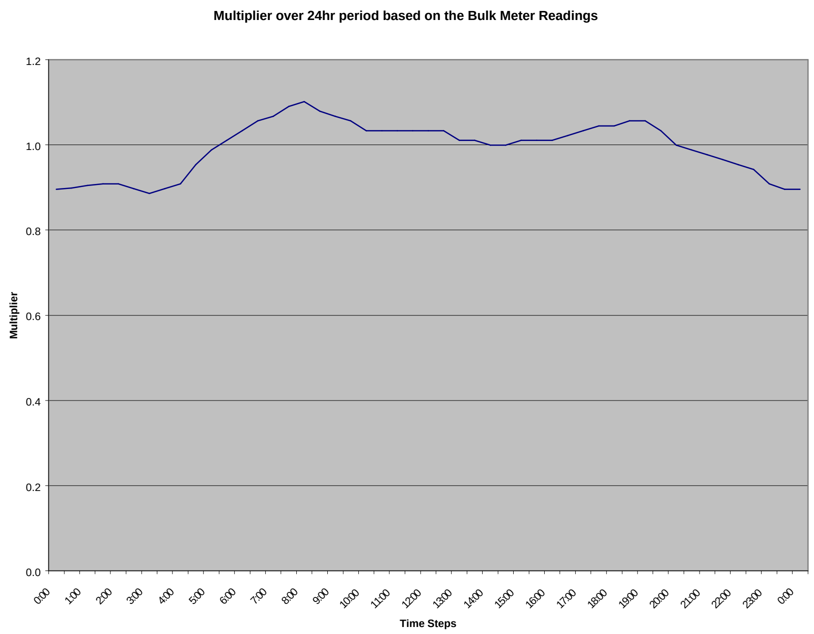


Figure 4: New multiplier as taken from bulk meter readings at Matakieua

Because the districts did not coincide with the billing blocks, for instance, in some areas two districts would divide one billing block and the district meter would only read what's going into each district but that does not necessarily correspond to the amount of flow that would show up on the billing block reading due to losses on the main. The most accurate figures to be used for the demand would be the billing block reading. Thus, the billing block demand was used and the demand pattern was taken from the district meter.

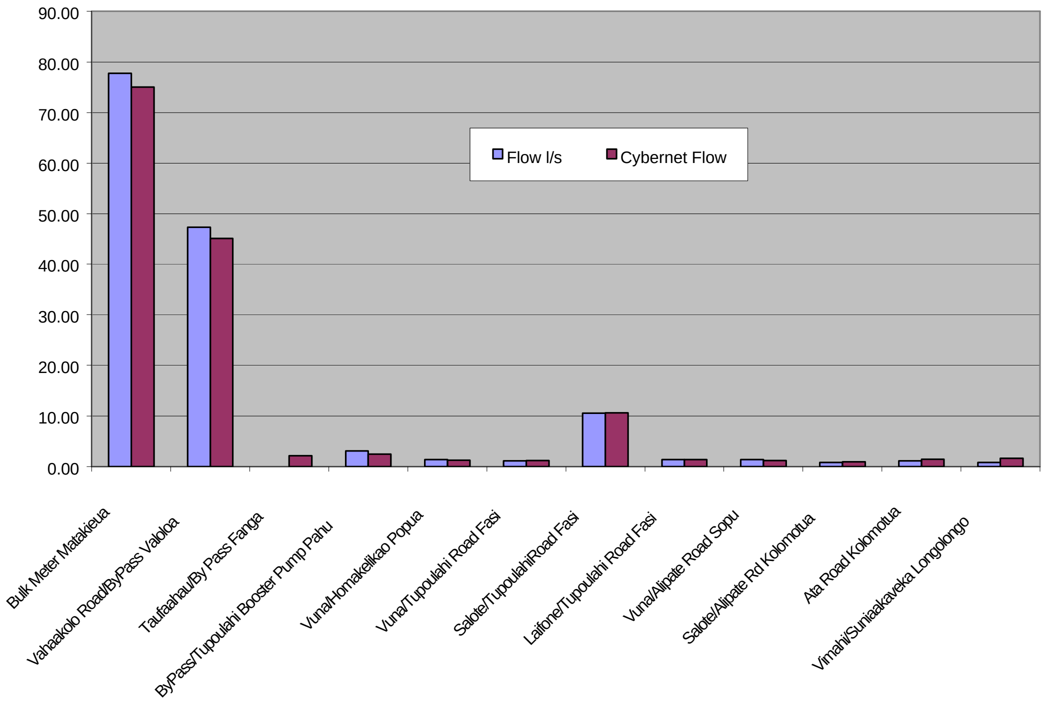


Figure 5: Measured and computed district meter in litres per second at 2:00 AM

Table 5: Measured and computed district meter in litres per second at 2:00 AM

Meter ID	Location	Flow l/s	Cybernet Flow
1	Bulk Meter Matakieua	77.78	75.00
2	Vahaakolo Road/ByPass Valoloa	47.30	45.11
8	Taufaahau/By Pass Fanga		2.14
6	ByPass/Tupoulahi Booster Pump Pahu	3.06	2.46
7	Vuna/Homakelikao Popua	1.39	1.27
VW3	Vuna/Tupoulahi Road Fasi	1.11	1.18
5	Salote/TupoulahiRoad Fasi	10.56	10.59
VM4	Laifone/Tupoulahi Road Fasi	1.39	1.37
VM2	Vuna/Alipate Road Sopu	1.39	1.16
4	Salote/Alipate Rd Kolomotua	0.83	0.91
VM1	Ata Road Kolomotua	1.11	1.47
3	Vimahi/Suniaakaveka Longolongo	0.83	1.66

These were entered onto a different scenario in Cybernet and then later Cybernet calculated the different time steps. This gave us a much better result but slightly out. So we took the 2.00 am (roughly the Minimum Night Flow) reading on the district meters and after adjusting the leakage (or UAFW) we were able to produce a reading that was closer or the same as the district meter without altering the usage of the billing blocks. This was a better approach and not only did it give us a better result, we could identify areas with reasonably high leakage. To assume that 40mm pipes and 300mm pipes would leak the same, was misleading[6]. So the leakage was assigned to the AC mains which account for all the leakage that the TWB has faced since the AusAID-funded institutional strengthening project initiated a thorough leakage detection and fixing program.

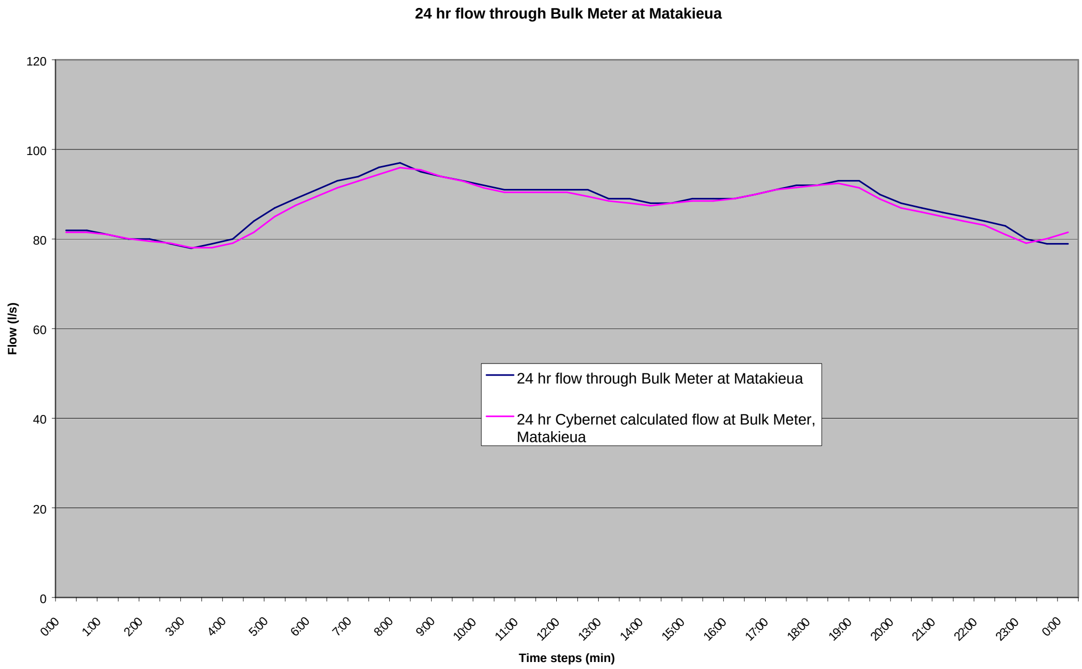


Figure 6: Meter readings and calculated flows over a 24 hour period for the Matakieua bulk meter[7]

The calculated pressure head was also compared with the manual reading. The manual readings were little bit lower than the calculated by about 1.5 to 2 meters. This was due to the fact that the readings were taken from fire hydrant which was about 2 meters

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[6] This particular problem shows again the benefits of having model and GIS connected for the GIS provides relatively easily to handle tools to perform such operations as computing leakage according to pipe sizes.

[7] The reader might have realised that the excellent accordance between measured and computed flows is a direct result of the method used. After all the flow and the multiplier have been derived from the bulk meter readings. However, it proves that the overall demand of the system has been set correctly.

above the mains and the calculated pressure head were from the top of the main. Thus accordance between measured and computed pressures is deemed satisfactory.

One other noticeable result was between the Bulk Meter at Matakieua and the Vahaakolo District Meter there is a significant drop in the HGL (pressure) during peak hour, for instance from 25m at Matakieua down to 5m at Vahaakolo District Meter. There were very high flows along this main, up to 57 l/s and this was causing the high friction losses.

They only problem we faced with this option was that we could not model district 7 which was to the far east of Nuku'alofa, which was one of the low-pressure areas. This option computed negative pressure, which is physically impossible. This area gets very little flow during the day and they only get water during the night as the other district's water consumption drops.[8]

The quality of the results and their good accordance with measured values show that the model calibration process was successful. Nevertheless some problems remain to be addressed, e.g. the booster pump set up which could only be modeled based on assumptions rather than facts about the pump, controls and flow rates. The same applies to the tanks at Matakieua for which only incomplete data on water levels was available. But it should be stated that the development or the application of a network model is no static process. System data changes permanently over time and so should do model. Data collection efforts should not slack off and new information should be processed continuously. Finally the model provides an excellent reference against which actual performance should be measured.

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[8] *This is, as already stated, a general problem of numerical modeling of water supply systems. In order to correctly reflect district meter reading it would have been necessary to reduce imposed demands to the measured levels. But then the 'demand' would no longer be a real demand but the amount of flow available to the population in the relevant area. As described the 'negative computed 'pressure' shows that the imposed demand cannot be met, hence that the system has deficiencies that do not necessarily originate from the particular area.*

The proposed upgrading under the Japanese Emergency Fund

As stated earlier, TWB is about to upgrade the Nuku'alofa water supply system with Japanese support (Figure ??). It consists of increasing pipe sizes and dividing the water supply system into two independent zones. Unlike the Master Plan Solution suggested by PKK there is no pressure boosting through pumps or elevated tanks. That has the clear advantage of reducing operational costs and reducing maintenance requirements. However, it also limits the available HGL to the level of the tanks at Matakieua at any time (with the exception of the already existing booster pump that serves a very small part of the population only). The calibrated model was used to test the proposed solution. Demand levels and controls etc. remained the same.

The results show a clear improvement to the status quo. Appendix summarises them graphically. It is likely that the real situation will provide even better results in terms of pressure because of the high leakage level that has been imposed on the system. This leakage is supposed to reduce dramatically with the laying of new pipe mains. As a result flow rates will reduce and hence headlosses, providing higher pressure to consumers. Insofar as the chosen method of testing the alternative is concerned, it provides conservative results.

However, similar effects could be achieved by concentrating leakage detection and fixing on the area between Matakieua and Vahaakolo bulk meter where large portions of the pumped water apparently enrich the groundwater than finding their destination. It should also be acknowledged that maximum HGL will be always below the approx. 25 m maximal available HGL. Some parts of Nuku’alofa will be hardly better off with the new system.

The results have been attached in graphical form as Appendices 3 and 4.

Conclusions

I think this Attachment Work was a success with calibrating the TWB Water Reticulation Network. The time I spent with Harald Schölzel(SOPAC) was very interesting and I have gained a lot of experience, not only in engineering aspects, especially with hydraulics, but I have also learned more about hydraulic programs like Cybernet, but other programs like MapInfo, Vertical Mapper and Data Base Connection.

The time I spent here with SOPAC Water Resource Unit was well-spent. This whole workshop is benefiting the Tonga Water Board and myself and I'm looking forward to more involvement with SOPAC in the future.

There are still a few minor things that I need to do when I get back to Tonga and then adjust the model. This is mainly due to pipes linking or not, according to some of the older staff they don't, but GIS shows that it does. Also I would have to double check on the booster pump's characteristics.

The outcome of this whole calibration is work outlined in this report plus a copy of the model, spreadsheets and MapInfo tables which contain existing conditions in comparison with the calibrated output of Cybernet.

The attachment and its outcome has been a great pleasure for me to and it clearly shows the potential Pacific Island Countries Engineer and Technicians have when given the opportunity (and time). The apparent success of this attachment encourages SOPAC Water Resources Unit to further increase the availability of such attachments. It should even more encourage member countries to make their staff available to such concentrated training exercises that show immediate results to the country in terms of human resources development and direct impacts on ongoing projects.

References

PPK Consultants Pty. Ltd. in association with Riedel & Byrne Pty. Ltd. 1992, Master Plan Studies for the Kingdom of Tonga.

Schölzel, H. 1999a. A summary of pipe location technologies: compiled on behalf of the Tonga Water Board. SOPAC Technical Report 272. 15 p.; 1 app.

Schölzel, H. 1999b. Hydraulic modelling of the Nuku'alofa water supply system, Kingdom of Tonga. SOPAC Technical Report 273.64 p.; annexes.

Appendix 1: Daily Activities

Saturday 31 June

Arrive in Nadi Airport from Tonga
Caught Bus to Suva
Rang Herald about Workshop
Met up with him later to discuss workshop

Sunday 1 Aug

Rest day

Monday 2 Aug

Arrive at SOPAC office 8.00am
Met Herald and was introduced to SOPAC Staff
Had IT set me up with an account on the network & installed MapInfo & Cybernet on to my PC
Downloaded Tonga data from my laptop to my PC
Set up workspace on my PC on TWB Water Reticulation Network
Briefed Herald on the progress we have on the GIS back in Tonga
Briefed Herald on a Model I set up with Japan Design Team back in Tonga on their proposed upgrade to TWB Water Reticulation Network
Briefed by Herald on exporting & importing data from MapInfo to Cybernet & vice versa
Imported Cybernet nodes to MapInfo and than sorted them out into which districts it belongs to according to district set up on MapInfo
Computer seems to be terribly slow. To do complicated calculation you would need to have a powerful PC able to handle the switching from program to another without having any difficult like it is now.
Finished for the day 5.00pm

Tuesday 3

Arrive SOPAC office 7:30am
Continued with zoning of nodes to appropriate district using Column Update on MapInfo
Email Kolo in Tonga to collect data on Booster Pump
Discussed with Herald about Cybernet Model and merged the model of existing TWB Water Reticulation Network and Model I did with the Japan Basic Design Team
Had problem with projection because MapInfo junction did not coincide with Cybernet node
Fixed problem
Briefed on how to set up database connection between Cybernet and MapInfo using MS Access
Setup connections
Briefed on Cybernet synchronizing in & out

Wednesday 4

Arrive SOPAC office 8.00am
Briefed by Herald on Canadian Team visiting SOPAC on GIS work
Arranged that I could show them the GIS work of TWB
Continued more work on database connection
Continue more work on synchronizing in & out
Updated both data on Cybernet & MapInfo via synchronizing in & out
Discussed with Herald how we could calibrate demands

Emailed Kolo to sent me Billing Blocks from Tonga
Collected data Litia on contours of Nuku'alofa
Brief on how set elevation on nodes on model by using vertical mapper
Arrange for IT to install vertical mapper on my PC
Briefed on how to use Vertical Mapper by Litea
Grouped RL with same height to reduce the data into a small size so VM could tolerate
Used VM on Nuku'alofa Contours and projected 3D images
Left for home 7.00pm

Thursday 5

Arrived SOPAC 8.20am
Continued on VM
Added 5 m contour & used the work done yesterday we could interpolated the height to fill in area around Popua & Sopu which did not appear on table from Litea's data.
Converted VM contour lines into contour levels and using the upper value
Combine tables of contour regions and Cybernet junction therefore letting MapInfo calculate a RL for each junction or node and then synchronizing it back in to Cybernet model via MS Assess.
Emailed Tonga about more information required for the calibration.
Did some work on the Nuku'alofa water demand
Still awaiting information from Tonga

Friday 6

Arrived SOPAC office 8.00am
Received email from Graham in Tonga that they will sent the data soon
Discussed with Herald on ways to calibrate the model using controls to adjust the demands to each district meter.
Used the Billing Blocks to calculate demands for the model
Set a spreadsheet on excel to calculate % of the junction is commercial or domestic therefore allocating a demand to it
Allocated each node into the billing block it is contained
Synchronized it back into Cybernet
Finished work 5.00
Had BBQ with German visitors together with SOPAC staff

Saturday 7

Rest Day

Sunday 8

Rest Day

Monday 9

Arrive SOPAC 8.30
Continued more work on water demand
Updated information received from Tonga on Booster Pump onto model
Discussed with Herald the demand calculation
Demand seem to be to low
Awaiting more information from Tonga
Updated TWGIS Data by doing some queries.
Discussed more with Herald on the demand

Did more calculation on excel spreadsheet.

Tuesday 10

Arrive SOPAC 8.15
Continued more work on excel spreadsheet
Discuss with Herald water Demand.
Decided to use a different approach to the demand on the junction because the current did not give out the required output
Added more information data to TWB GIS
Synchronized it back to Cybernet
Did some SQL to be able to calculate demands on MapInfo

Wednesday 11

Arrive SOPAC 8.00
Used MapInfo SQL to update table fields
Discussed with Herald how we would attempt to distribute the demand patterns
Emailed Haestad problems we faced with the model
Found out the a composite demand could not be altered globally but individually which was a problem
Tried to work out a method to solve this problem
Because there was more domestic connection than commercial we decided to distribute all the demands both Domestic, Commercial and Leakage into each junction and the total demand is input in the model therefore using the existing demand pattern

Thursday 12

Arrive SOPAC 8.00
Set up Spreadsheet on all demand patterns
Set up multipliers (existing from Master Plan)
Set up averages and then working out a new multiplier
Faced a problem that I would have to have a demand pattern for each junction which very complicated job
Decided to set up different average and work out the variance in the multiplier, therefore I cold work the appropriate multiplier depending on the variance and how it will affects the model.
This method is not the exact but it will model the network as close as possible to what it really happening on the field
Set up spreads sheet work out variance
Now one Demand Pattern which combines all 3 Domestic, Commercial and Leakage
Used that variance table to pick the best average value to project the real demand multiplier
Plot it on graph and compared with the existing demand pattern from the master plan and it looks pretty good
Checked with Herald and he gave me the OK
The new corrected demand is probably out by 10%, which seem reasonable

Friday 13

Start SOPAC 8.25
Updated some fields to MapInfo which work vice versa with Cybernet
Set up demand pattern on Cybernet
Synchronized to demand from MapInfo into Cybernet

Let the Cybernet run on a Steady state analyses determines the operating behavior of the system at a specific point in time, or under steady-state (unchanging) conditions. This type of analysis can be useful for determining short-term effects on the system due to fire flows or average demand conditions.
Found that the model was only running on a demand of 34.621l/s which was short by 53 l/s
Leave SOPAC 5.30

Saturday 14

Rest day

Sunday 15

Rest day

Monday 16

Arrived SOPAC 8.15
Investigated problem from Friday
Found that the leakage demand was not included
Total demand was than calculated via MapInfo and synchronized back into Cybernet.
Later realized that MapInfo interpreted the valves and pumps, as junctions therefore allocating demand to them.
This is due to way Cybernet models a valve behavior by the upstream (from pipe) and down stream behavior (down pipe).
This also affected the number of junction per billing block and therefore affecting the demand per junction per billing block.
I had to correct the number of junction therefore the % of demand was less and would reflect back on the models demand. This had to fix by start from the spreadsheet and working my way back
This whole process was completed and MapInfo Table was updated and ready to be synchronized in Cybernet.
During this process I accidentally lost all my data
Did more work with TWB GIS until I retrieve a back from my laptop

Tuesday 17

Arrive SOPAC 8.30
Retrieved back up
Adjusted the backup to the present state of the calibration process and input into MapInfo Table
Rebuilt the MS access connection
Synchronized the data from MapInfo in Cybernet
Ran the model on Steady State Network Hydraulics analysis
Steady state analyses determine the operating behavior of the system at a specific point in time, or under steady-state (unchanging) conditions. This type of analysis can be useful for determining short-term effects on the system due to fire flows or average demand conditions.
For this type of analysis, the network equations are determined and solved with tanks being treated as fixed grade boundaries. The results that are obtained from this type of analysis are instantaneous values, and may or may not be representative of the values of the system a few hours or even a few minutes, later in time.
The result still did not match the manual output.

Had to go back and check the input data
Decide to use the district meter and bulk meter to determine a different pattern
Set up district and bulk meter reading in to a spreadsheet to calculate flow into each district
Realized there was an error in the monthly readings so had to use a daily reading.

Wednesday 18

Arrive SOPAC 8.30
Continued working on where finished on Tuesday
Calculated the average daily flow to 88.06 l/s and minimum night flow of 77.08 between 1.00 am and 2am
Looking at the flow pattern from the bulk meter it was different from the pattern I had been using
A new pattern was then design base on the flow pattern of the bulk meter at Mataki'eua
Tried to contact TWB office for raw data from logger when it was set up at the bulk meter but not get through due line congestion
Email Tim Waldron for raw data from logger but could locate him
Decide to use the graph from the logger to generate some time step and flow
Graph was traced and set up on grid paper to calculate time steps
This was entered in to a spreadsheet and using the average daily flow a new multiplier was than calculated.
This was enter into the Cybernet model

Thursday 19

Arrive SOPAC 8.30
Ran the model
Results were very pleasing
Model still had to adjusted to give the nearest reading to the district meter's manual reading
Recalculate the leakage
Assign it back in to the demand and re calculate the model
This was done until it got the best result
Still did not come as close as I would have like, around 10%

Friday 20

Arrive SOPAC 8.30
Continued adjusting the leakage
Decided on adjusting it to the AC mains by not evenly distributed it around the junctions
Finally came as close as the to the district meter.
Around +/- .45 l/s

Monday 23

Arrive SOPAC 8.30
Because I adjusted the leakage on Cybernet I need to update MapInfo of the total demand
It was than synchronized back
Some on the process the data base was corrupted
Tried to fix it
After it was fixed the data was again synchronized back in to MapInfo
The leakage was than adjusted
The maps were than generate to compare the calculated results against the manual readings
Result were quite pleasing

Left 7.30pm

Tuesday 24

Arrive SOPAC 8.30
More maps printed
Worked on the report
Left 6.30pm

Wednesday 25

Arrive SOPAC 8.30
Worked on the report
Left 7.00pm

Thursday 26

Arrive SOPAC 8.30
Continued with report
Discuss with Harald the Japan Proposed Upgrade
Run the calculated pressure against the manual readings and were very close
The result a success
Power Black Out, could do any more work
Invited to Harald house for BBQ

Friday 27

Ran the model against the Japanese proposal
Compared result and to what extend?
Finish off report
Workshop concludes

Appendix 2: Modes of Analysis

Steady State Network Hydraulics

Steady state analyses determine the operating behavior of the system at a specific point in time, or under steady-state (unchanging) conditions. This type of analysis can be useful for determining short-term effects on the system due to fire flows or average demand conditions.

For this type of analysis, the network equations are determined and solved with tanks being treated as fixed grade boundaries. The results that are obtained from this type of analysis are instantaneous values, and may or may not be representative of the values of the system a few hours or even a few minutes, later in time.

Extended Period Simulation

When the effects on the system over time are important, an extended period simulation is appropriate. This type of analysis allows the user to model tanks filling and draining, regulating valves opening and closing, and pressures and flow rates changing throughout the system in response to varying demand conditions and in response to automatic control strategies formulated by the modeler.

While a steady state model may tell whether or not the system has the capability to meet a certain average demand, an extended period simulation indicates whether or not the system has the ability to provide acceptable levels of service over a period of minutes, hours, or days. Extended period simulations can also be used for energy consumption and cost studies, as well as water quality modeling.

Data requirements for extended period simulations are greater than for steady state runs. In addition to the information required by a steady state model, the user also needs to determine water usage patterns, more detailed tank information, and operational rules for pumps and valves.

Appendix 3: Detailed Results for particular network elements

(22 pages plus overview map)

Appendix 4: Results

Appendix 5: Japanese Upgrading Proposal