University of Southern Queensland

Faculty of Engineering and Surveying

Short-Term Water Demand Forecasting for Production Optimisation

A dissertation submitted by

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in fulfilment of the requirements of

Courses ENG4111 and 4112 Research Project

towards the degree of

Bachelor of Engineering (**Environmental**)

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For my parents

Abstract

This study comprises the formulation of a short-term (24 hr ahead) water demand predictive model using multiple variable linear regression technique for the purposes of production optimisation and water demand management for Toowoomba City Councils Mt. Kynoch Water Treatment Plant. It includes a consumption trend analysis and investigation of the impact of demand management techniques utilized by TCC in reducing water consumption.

The results were comprehensive and indicated that Toowoomba's demand is quite strongly affected by maximum air temperature, rainfall and rain-days, moving average demand, 4-day weighted average demand, as well as imposed restriction levels. An attempt to combine rainfall and rain-days into a single variable called rainfall-weighting produced exceptional results given the short duration of data analysed.

Toowoomba's next day water demand can be quite accurately forecasted using a multi-variable linear regression model with the following specifications:

Forecasted Demand = 3.58 + 0.17×Temperature – 0.1×Rainfall – 2.41×Rain-days + 0.85×4-day Weighted Average Demand – 0.33×Restrictions

It is recommended that TCC formalise its short-term forecasting system for production optimisation and implementation of demand management polices. A minimum level of restriction should also be applied to engineer conservative water use behaviour even in better times.

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ENG4111 & ENG4113 *Research Project*

Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Student Number: 0039530903

Signature

Date

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I am indebted to many people along the way to the completion of this dissertation. First and foremost, I am grateful to Mr. Peter Clark and Toowoomba City Council for proposing and facilitating this project. I am particularly grateful to Dr. David Thorpe, my principal supervisor, who was not only available for his excellent academic and technical support, but provided continuous encouragement throughout the year. Mr. Gareth Finlay's understanding and expertise on the area proved to be invaluable and his timely advice and ever-availability, sometimes at short notices, is very much appreciated. Mr. Ron Merry and Mrs. Sonia Anderssen's eagerness to assist in administrative and resource areas were immense and duly appreciated as well. Lastly, this would not have been possible without the continued support of my family, especially my wife, Sharmila.

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Nomenclature and Acronyms

ABS	-	Australian Bureau of Statistics
AHD	-	Australian Datum Height
ANN	-	Artificial Neural Networks
ARIMA	-	Autoregressive Integrated Moving Average
BWL	-	Bottom Water Level
C1	-	Cressbrook Pumping Station 1
C2	-	Cressbrook Pumping Station 2
DN525	-	Outside Diameter of Mains (mm)
ETM	-	Eastern Trunk Mains
GDA	-	Geodetic Australian Datum
L/s	-	Litres per second
ML	-	Mega litres
mg/L	-	Milligrams per litre
ML/d	-	Mega litres per day
MSCL	-	Mild Steel Cement Lined (pipes)
NWTM	-	North-West Trunk Mains
OTM	-	Old Trunk Mains
Qld	-	Queensland
RL	-	Reduced Level
SST	-	Total Sum of Squares
SSR	-	Regression Sum of Squares
SSE	-	Residual Sum of Errors
TCC	-	Toowoomba City Council
TH	-	Total Hardness
TWL	-	Top Water Level
WTM	-	Western Trunk Mains
WTP	-	Water Treatment Plant

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

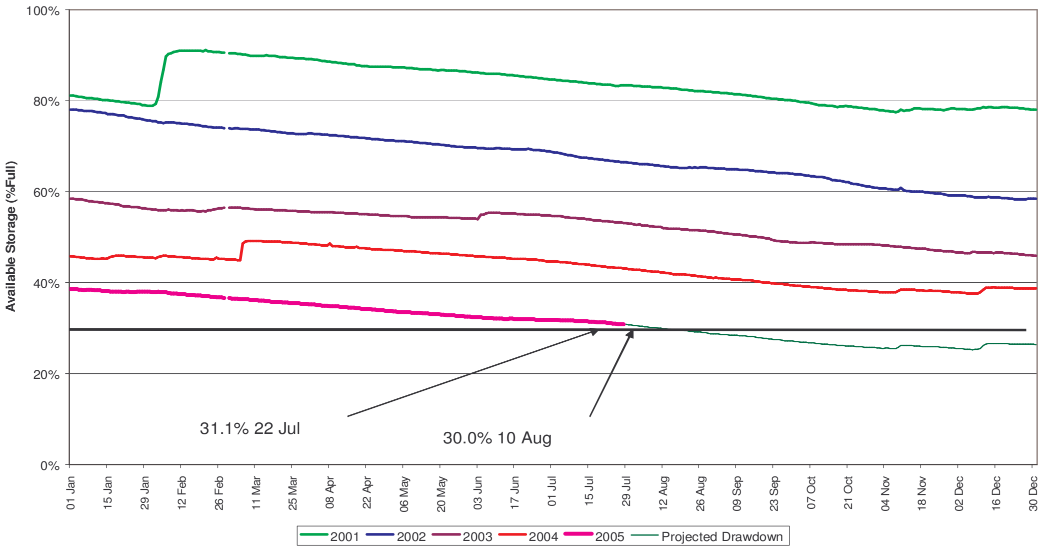
'THE FUTURE IS LIKELY TO BE SHAPED BY WAR FOR WATER …..' (Time Magazine)

As the world's population grows, so does the demand for freshwater supply. A recent United Nations report affirms that global freshwater consumption has risen six-fold between 1990-1995, more than twice the rate of population growth (Beaudet and Roberts, 2000). This has imposed considerable demand on water resources and resulted in depletion of global water resources. Zilberman & Lipper, (1999) have not only highlighted the emergence of sustainable water resource management as an unconditional issue, but also advocated this as one of the most important tools in future water demand management. Toowoomba, in Southern Queensland is no exception to this worldwide trend.

The problem facing Toowoomba City Council's (TCC) Mt. Kynoch Water Treatment Plant (WTP) is to meet the city's increasing demand for water at a time when supply is decreasing rapidly. The above is perfectly illustrated in figure 1.1 which indicates how the primary water storage has declined consistently during the last 5 years and is due to reach precarious levels by the end of the year. This is further compounded by below average rainfalls received in the region and more importantly in the catchment area and is graphically illustrated in figure 1.2.

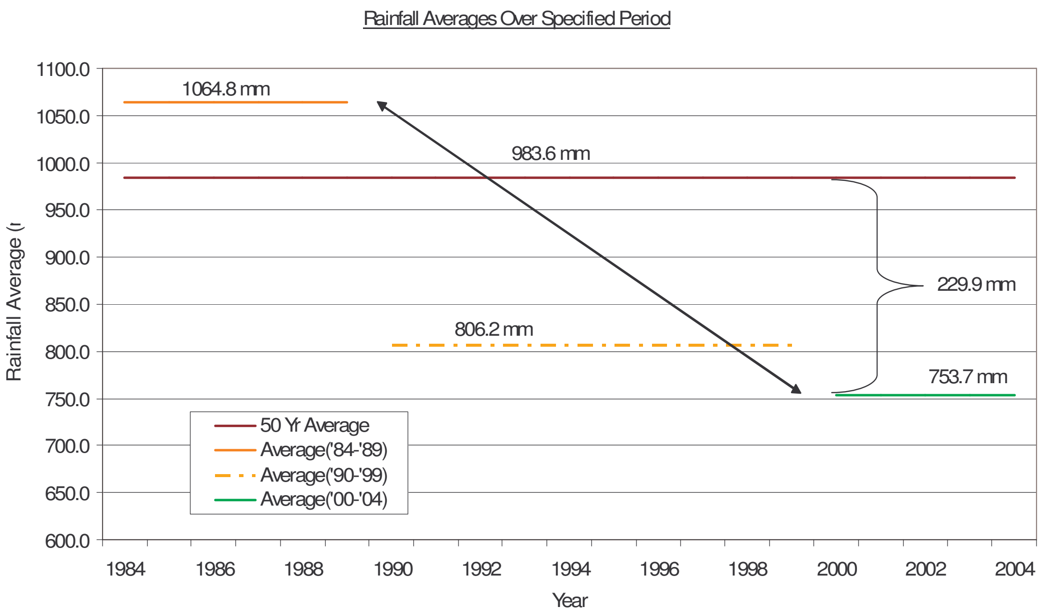
The traditional solution to exploit new water resources commonly referred to as supply augmentation, at the moment is out of question because of associated capital costs and the distance of delivery of raw water to Mt. Kynoch WTP. Apart from the capital and operational expenditure incurred, supply augmentation also harbours serious environmental costs from ecosystem degradation such as depleting existing aquifers, damning rivers and destroying wetlands in the process (Horgan, 2003).

Figure 1.1: Toowoomba's Storage Trace



Source: Toowoomba City Council

Figure 1.2: Reduction of Rainfall Averages over Past 20 Years



This has propelled TCC to seriously explore and implore options to decrease the demand through several demand management methods. However, for effective demand management and conservatory tools and methods to be practised, requires accurate short-term demand forecasting techniques, especially ranging from 24 hours to a week ahead. Accurate predictions will not only allow application of appropriate water management methods but also facilitate for the optimisation of production, which will further reduce the daily operational expenditure.

1.1 Project Objectives

This project is carried out in two stages, to fulfil the final year requirements of two parallel courses, namely ENG4111/4112, commonly referred to as *Engineering Research Project* outlined in appendix A and will try to achieve the following broad aims:

1. Research background information and literature relating to demand forecasting and demand management.
2. Analyse water consumption trends for City of Toowoomba.
3. Data acquisition and quality analysis of appropriate duration of data.
4. Develop an appropriate demand prediction model. .
5. Compare model results with other similar demand forecasting models.
6. Prepare and submit the required project dissertation as per Project Reference Guide, 2005.

1.2 Dissertation Overview

In essence the project is presented into several chapters as follows:

- Background of Toowoomba
- Overview of Mt. Kynoch Water Supply Infrastructure
- Literature Review
- Methodology
- Results
- Discussion and Recommendations
- Conclusion.

CHAPTER 2

BACKGROUND

2.0 BACKGROUND

Toowoomba is located approximately 130 km west of Brisbane *(figure 2.1)* in the Southern region of Queensland at an altitude of 650 metres AHD with the following geographical coordinates:

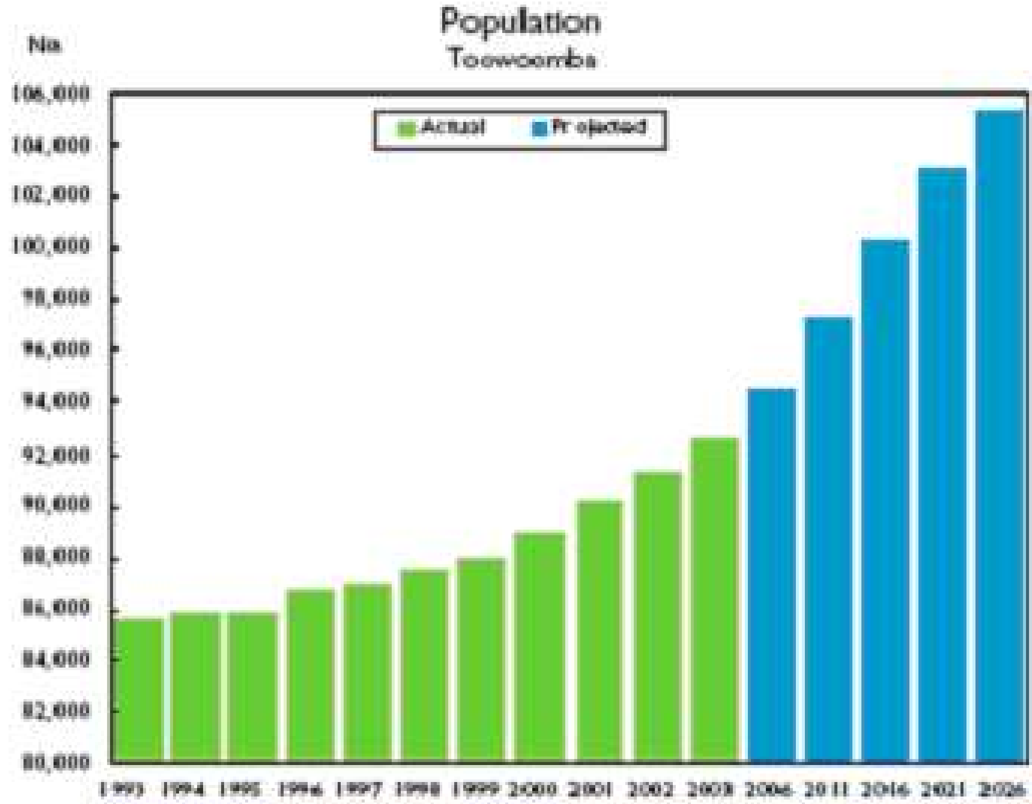
Latitude : South 27 degrees 33 minutes 52 seconds (GDA 94)
Longitude: East 151 degrees 57 minutes 7 seconds (GDA 94)

Figure 2.1: Location Map of Toowoomba

Source: Toowoomba City Council

As Queensland's largest inland city, Toowoomba currently has a population of approximately 93,000 (ABS, 2003) and as shown in figure 2.2, growing at averagely 1.4% per annum (Hunter Water, 2003). However, the water supply grid population as at June 2005 stands at 109,673. Being the hub of the fertile Darling Downs region has resulted in a city with extensive manufacturing, education, health, retail and professional services.

Figure 2.2: The Population Trend of Toowoomba



Source: Toowoomba City Council

The city is popularly known as the 'Garden City' and hence supports beautiful flower gardens all year around, attracting thousands of visitors, especially during the Carnival of Flowers. This signature event also puts millions of dollars into the local economy and is crucial for the survival of many smaller businesses in the Darling Downs region. However, this extraneous activity also exerts tremendous burden on the swindling water resources, and is under review from year to year, according to availability of water resources as to its continuity.

2.1 Toowoomba's Catchment and Waterways

Toowoomba sits in two catchments, *(see Appendix B)* and is made up of the:

- Eastern (flowing into south east Qld); and
- Western (flowing into the Condamine catchment in the Murray Darling Basin).

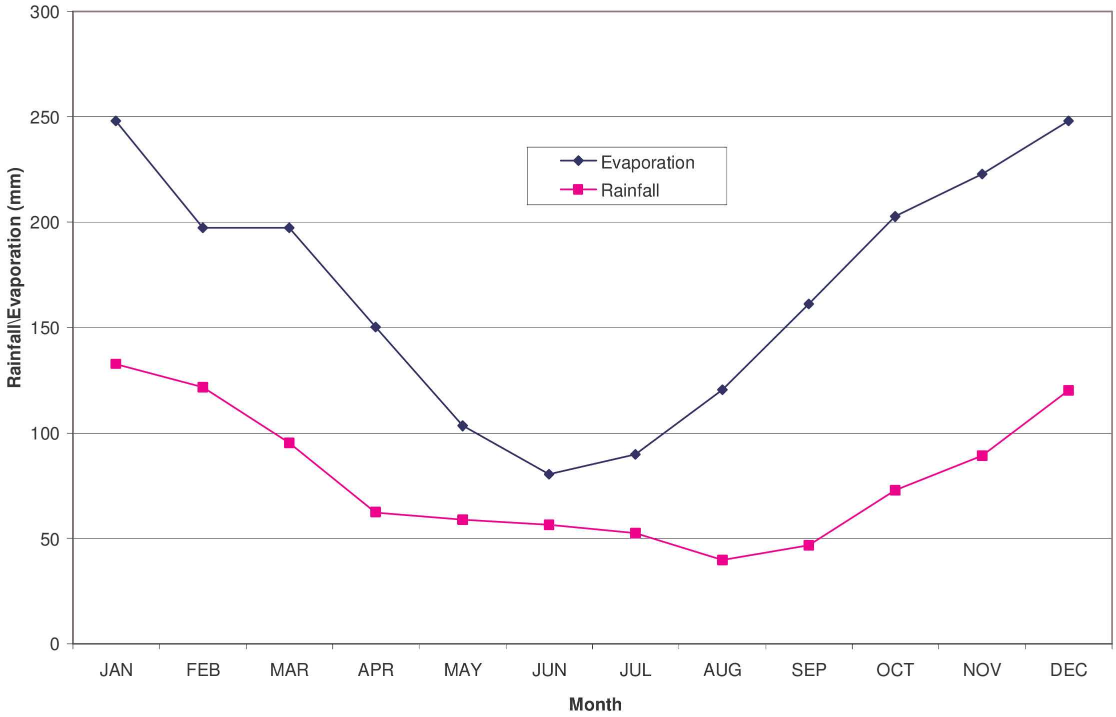
The waterways in the eastern catchment include various creeks along the length of the eastern escarpment and in parts of the southern escarpment. The major waterways of Toowoomba shown in appendix C are in the Western Condamine catchment, namely:

- Gowrie Creek;
- East Creek;
- West Creek;
- Black Gully;
- Spring Creek;
- Westbrook Creek;
- Dry Creek; and
- Smaller waterways of Gowrie Creek in the northern catchments.

2.2 Toowoomba's Climate

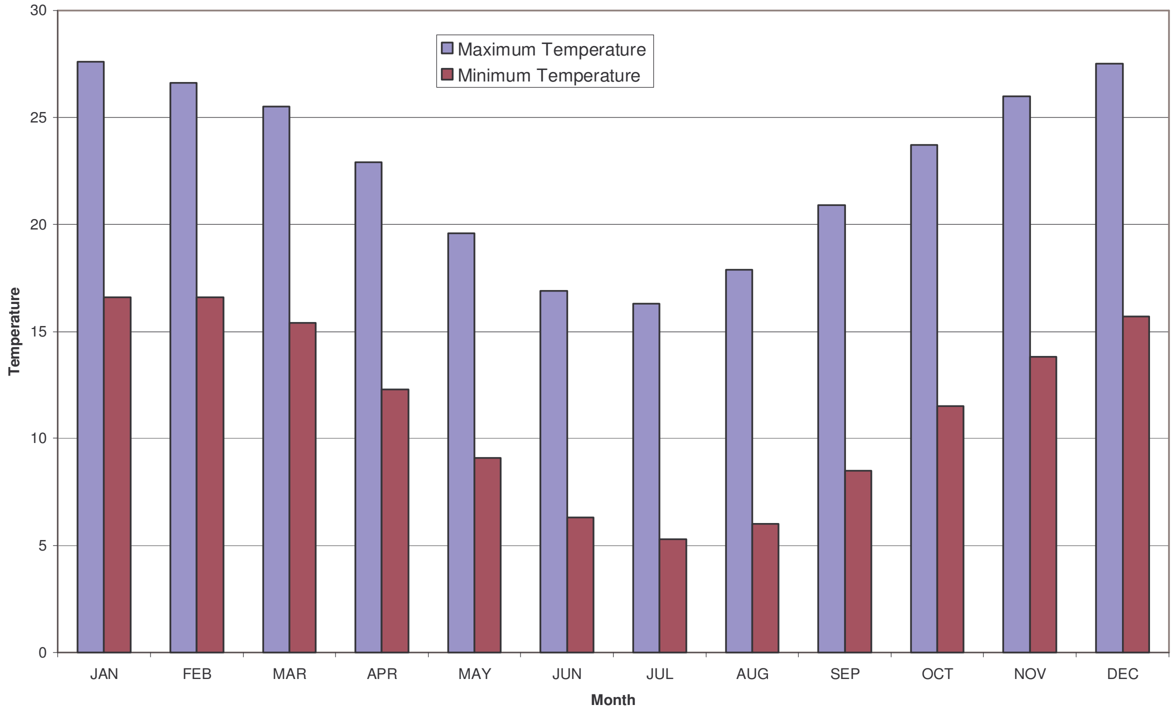
The mean annual rainfall in Toowoomba is 969mm, recorded at the Mt Kynoch weather station, which reports to the Bureau of Meteorology. Most rain falls in the summer although this is not as strongly seasonal as a typical climate as the mean driest month is about 30% of the mean wettest month. The monthly rainfall averages and monthly average evaporation are illustrated in figure 2.3. Morning fogs and dew are very common at Mt Kynoch. The humidity is fairly even, between 55 and 70%.

Figure 2.3: Toowoomba's Monthly Rainfall and Evaporation Averages



The maximum average summer temperature is 28^{O}C, and the minimum average winter temperature is 5^{O}C. The monthly average maximum and minimum temperatures are given in figure 2.4 below. Frosts in winter months are common, at Mt Kynoch, but less common than the valleys below. The region is exposed to winds from all directions due to the 360º views and elevated position. The predominant wind is from the east, but winter brings cold westerly winds. Toowoomba has experienced some severe hailstorms, the most notorious in 1976 (Holland, 2001).

Figure 2.4: Toowoomba's Average Maximum and Minimum Temperatures



Dry winters appear to have a seven-year cycle, associated with the El-Nino effect, with almost no rain for the entire winter months. Current rainfall patterns and the Southern Oscillation Index indicate that wetter seasons are ahead, after a prolonged drought.

CHAPTER 3

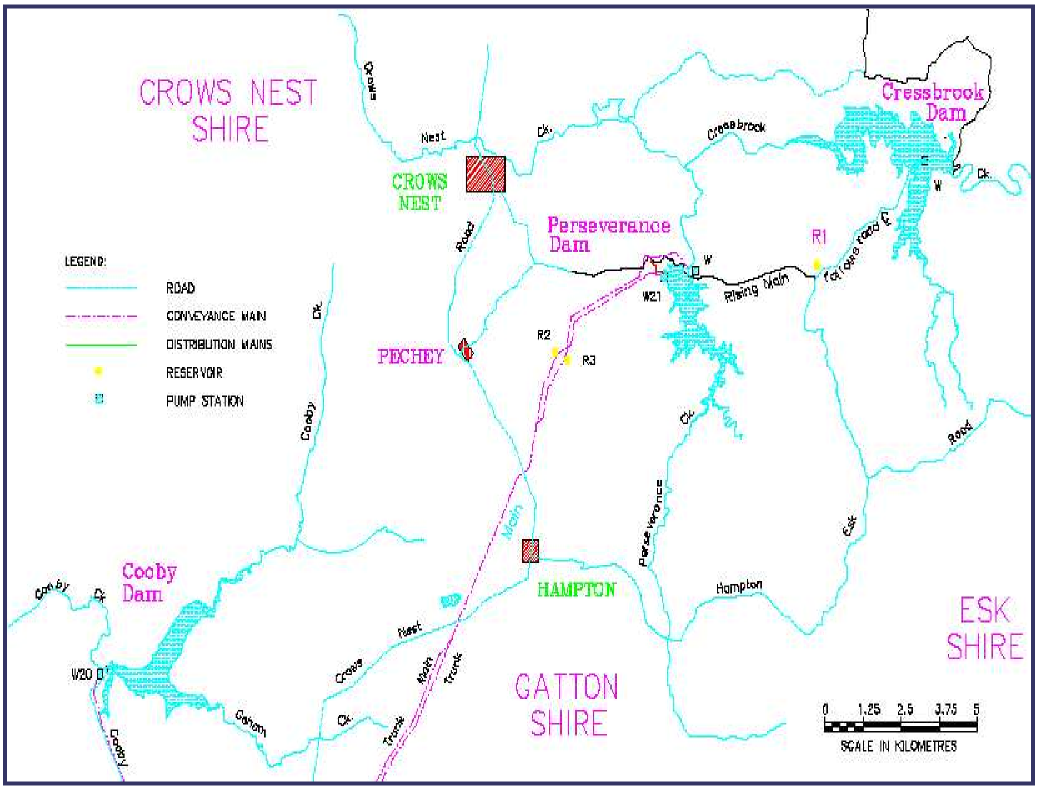
OVERVIEW OF MT. KYNOCH WATER SUPPLY INFRASTRUCTURE

3.0 OVERVIEW OF MT. KYNOCH WATER SUPPLY

3.1 Introduction

Present water demand and projected increases in water demand are deemed to have a significant impact on the future capacity of Toowoomba's water supply system. Hunter Water Australia (2003) has recently carried out an assessment and analysis of the Mt. Kynoch Water Treatment Plant Complex along with a review of operational strategies for optimising the delivery of raw water to the treatment facility. In light of above, this section primary focuses on presenting an overview of the existing infrastructure and capacity, while commenting on proposed projections and future expansion plans.

Figure 3.1: Location of Toowoomba's Raw Water Storages



Source: Toowoomba City Council

3.2 Primary Supply System

The regional system sources its surface water supply from primary surface storages at Cooby, Perseverance and Cressbrook lakes (*figure 3.1*). Raw water, with the exception of demand from the Crows Nest Shire (which provide their own treatment plant), is then treated at the Mt. Kynoch Water Treatment complex before it is distributed to the Toowoomba City's reticulation and to demand from external centres. These can be located in Appendix D.

3.2.1 Raw Water Conveyance

3.2.1a Cooby Dam System

Lake Cooby, constructed in 1939 with active pumping commencing in 1942. It is the oldest surface water storage, and is located some 17 km north of Toowoomba *(refer to figure 3.1)*. It lies on Cooby Creek, a tributary to Oakey Creek, which is a part of the Condamine River system. The lake's storage characteristics include:

Total Catchment Area	159 km^2
Maximum Capacity	23,092 ML
Maximum Usable Volume	21,036 ML
Top Supply Level at Spillway	478.54 m AHD

Water from Lake Cooby is pumped directly to the Mt. Kynoch treatment facility through a DN525 mild steel cement lined (MSCL) pipeline, approximately 15 km in length. The Cooby Pumping Station incorporates 3 pumps that can operate separately or in parallel, thereby varying pumping capacity as required. A booster station located at Highfields is used to increase supplies from the dam during periods of high demand. Operation of pumps located along the Cooby Pipeline is usually controlled by water demand at the water treatment complex, and can be run continuously through 24 hour periods.

3.2.1b Perseverance Lake System

Lake Perseverance is situated some 35 km northeast of Toowoomba along Perseverance Creek (a tributary to Cressbrook Creek). It is the second largest storage to be developed after Cooby, and was built 1965 and first commenced pumping in 1969, with the following characteristics:

Total Catchment Area	110 km^2
Maximum Capacity	30,140 ML
Maximum Usable Volume	26,668 ML
Top Supply Level at Spillway	446.08 m AHD

Lake Perseverance water is pumped approximately 5 km from the pumping station at the dam site, via DN750 mild steel cement lined rising main directly to the Pechey reservoirs. The Perseverance Pumping Station, which incorporates two pumps (duty/standby), is operated mainly during off-peak hours (9pm – 7am weekdays and all weekend) and controlled by the level at Pechey storage.

3.2.1c Cressbrook Lake System

Lake Cressbrook is the most recent and the largest of the three surface water storages. It was constructed in November 1983 but pumping wasn’t commenced until October 1988. The dam is located on the Cressbrook creek, some 10km downstream of lake Perseverance. Characteristic of Lake Cressbrook include:

Total Catchment Area	210 km^2
Maximum Capacity	79,983 ML

Maximum Usable Volume	78,847 ML
Top Supply Level at Spillway	280.00 m AHD

Water from the lake is initially pumped approximately 5km from Cressbrook Pumping Station No. 1 (C1) to Jockey Reservoir. Acting as balance storage, Jockey Reservoir conveys water to Cressbrook Pumping Station No. 2 (C2), a further 4 km away. C2 re-lifts water from Jockey Reservoir for an approximate length of 6km to Pechey storage reservoirs. Water conveyance is via a single DN750 mild steel cement lined pipeline.

C1 incorporates a set of priming pumps (duty/standby) at the base of the intake and two high level pumps (duty/standby), which are operated at off peak hours i.e. between 9pm – 7am weekdays, and primarily controlled by the level in Jockey Reservoir. C2 also incorporates two pumps (duty/standby) and is similarly controlled by time (off-peak), the level in Jockey Reservoir as well as the level at Pechey storage.

Table 3.1: Primary Raw Water Sources & Storages

Location	Catchment Area *(Km^2)*	Lake Area *(ha)*	Total Volume *(ML)*	Dead Storage *(ML)*	Total Avail. *(ML)*	Total Yield (ML/y)
Cooby Dam	170.9	301	23092	2056	21036	3182
Perseverance Dam	108.7	219	30140	3472	26668	7182
Cressbrook Dam	217.6	517	79983	1136	78847	11030
Bores						2100

Source: Toowoomba City Council, WTP

3.2.1d Gravity Conveyance Mains

Two interconnected reservoirs constructed on a ridge at Pechey, store pumped water from Perseverance and Cressbrook lakes. The reservoirs act as balance tanks and currently serve to supply water to the Mt. Kynoch Treatment Plant and Crows Nest Shire off-takes whilst restricting pump usage to off-peak tariff operation on Perseverance and Cressbrook lines.

Water then gravitates from the Pechey I & II Reservoirs via a dual, interconnected prestressed concrete pipeline, approximately 28 km to Mt. Kynoch treatment facility. The majority of this pipeline is constructed of DN675 prestressed concrete.

The bulk of the pipelines alignment is constructed within Crows Nest Shire and has off-takes that supply the townships of Crows Nest, Hampton and Highfields. Each off-take from the gravity line has their own water treatment facility before distribution to their respective demand centres.

Table 3.2: Primary Water Storage

Reservoir No.	Location	Usable Volume *(ML)*	Total Volume *(ML)*	% Usable Volume *(ML)*	TWL RL *(AHD)*	BWL RL *(AHD)*
R1	Jockey	3.800	5.030	75.55	588.390	557.910
R2	Pechey 1	6.500	6.758	96.18	747.133	741.833
R3	Pechey 2	11.54	15.62	73.88	746.860	741.833
Totals		**21.84**	**27.41**	**79.68**		

Source: Toowoomba City Council, WTP

3.3 Water Treatment Plant

Toowoomba City's water treatment plant is located at Mt. Kynoch near the northern boundary of the city and it currently has a hydraulic design capacity of 68 ML/d. However, a recent report (Hunter Water, 2003) has established that optimum efficiency capacity is less than the design capacity, and it has been proposed that the plant facility be upgraded to a capacity of 85 ML/d in the near future.

In order to maintain operating volumes at the Pechey Reservoirs that limit Cressbrook and Perseverance pump operation to off-peak tariffs, flows-rates through the gravity line are varied. Flow-rates through the gravity line control valve typically fluctuate in summer between 500 – 640 L/s during off-peak tariff periods and 250 – 400 L/s during peak tariff periods. The Cooby line mainly operates during periods of higher consumption, with pumped flows rates varied as required to meet demand requirements.

3.4 Treated Water Conveyance

3.4.1 Toowoomba Trunk Mains

Four major trunk mains convey treated surface water from Mt. Kynoch water treatment complex and consist of the Eastern Trunk Main, Old Trunk Mina, Western Trunk Main, and North West Trunk main. Appendix E shows the pressure zones that these mains service and their interconnectedness in a grid supply system means that multiple supply lines are available during periods of lower pressure during emergencies.

3.4.1a Eastern Trunk Main (ETM)

The ETM covers the eastern portion of the city and supplies Lofty, Picnic Point and Gabbinbar pressure zones. Although Horners pressure zone is typically fed by bore water, the ETM supplements this zone during times of high demands and/or bore stop/failure. Treated water is initially pumped to Mt. Lofty reservoir by the operation of pumps at Mt. Kynoch, where it gravitates to the Ramsay Street pumping station and pumps to Gabbinbar reservoirs.

3.4.1b Old Trunk Main (OTM)

The OTM conveys water by gravity from Mt. Kynoch to parts of Kynoch zone. It has been postulated to be dedicated to an new zone (Northern Pressure Zone – Appendix E).

3.4.1c Western Trunk Main (WTM)

The WTM covers central and western areas of the city, supplying water to Kynoch, Freneau Pines, Platz and Gabbinbar zones. City zone is also supplemented from this line during times of high demand and/or bore stop/failure. Rosalie and Jondaryan Shires indirectly draw off this line via the Oakey pipeline. Water along the WTM gravitates from Mt. Kynoch as far as the Anzac Avenue Pumping station, where it is then pumped to Platz and Gabbinbar pressure zones.

3.4.1d North West Trunk Main (NWTM)

The NWTM supplies western and southwest areas of the city. The Glenvale/Torrington area of Jondaryan Shire is also supplied by this line. The NWTM conveys water by gravity from Mt. Kynoch as far as the Anzac Avenue pumping station where it supplies parts of Kynoch zone as well as pumped to Gabbinbar and Platz zones.

3.4.1e Oakey Pipeline

The Toowoomba-Oakey Pipeline was constructed to serve demand centres within Jondaryan and Rosalie Shires. The pipeline will also supply future demands from the proposed Charlton/Wellcamp Integrated Employment Area Development.

The pipeline draws supply from Toowoomba City's Western Trunk Main and proceeds west along the Hermitage-Holmes Roads, and then along an easement corridor as far as Chamberlain Road. This section of pipeline is approximately 12 km long and consists of 375 mm diameter ductile iron cement lined pipe.

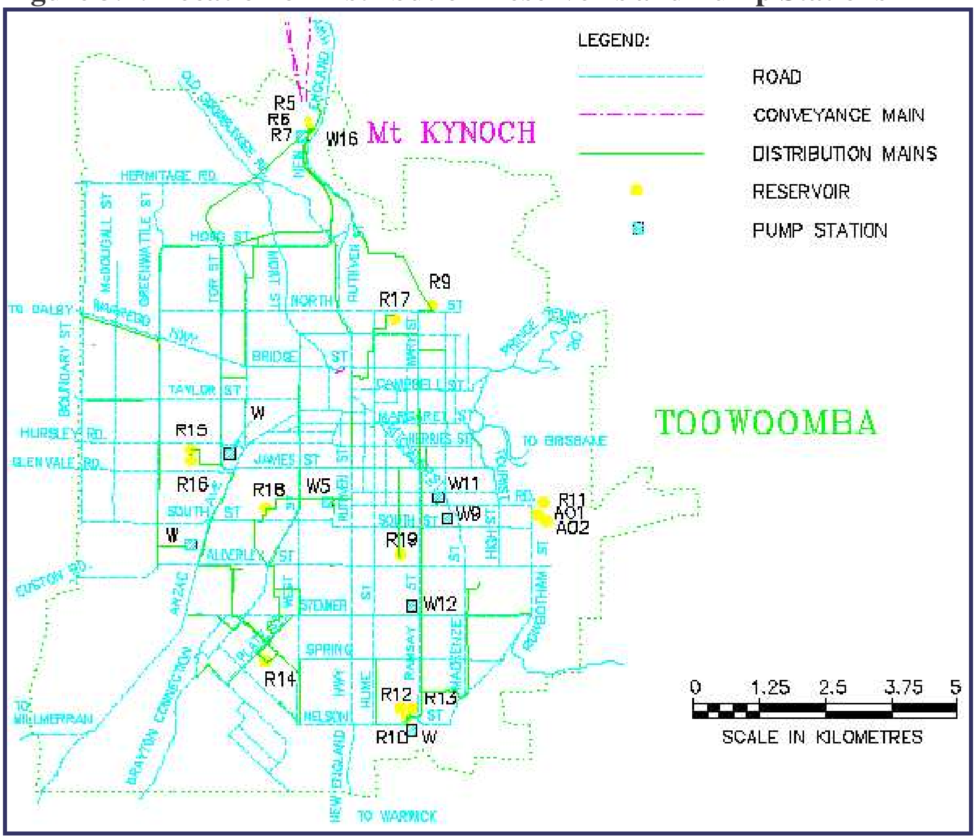
Off-takes along this section include supply to Gowrie Junction which also delivers to Goombungee and Meringandan West demand centres), supply to the proposed Charlton/Wellcamp area and delivery to

Kingsthorpe and Gowrie Mountain. Alignment of 300mm diameter ductile iron cement lined continues westward along the easement corridor connects to the Warrego Highway and proceeds along the highway to supply Oakey and Jondaryan.

3.5 Distribution Reservoirs

There are numerous treated water distribution reservoirs located at strategically chosen sites which allow water to be gravity fed into the supply network. Figure 3.3 and appendix D provides a summarised list of all treated water distribution reservoirs, its capacity and strategic locations.

Figure 3.2: Location of Distribution Reservoirs and Pump Stations



Source: Toowoomba City Council

3.6 Bores

Apart from the three main raw water storages, there are located numerous bores across the city to supplement the Mt. Kynoch facilities in critical times. While for most bores, the water quality is of exceptional standard, however, frequently, the water is treated for total hardness and hardness, which is of course characteristic of the area and hence cannot be avoided. Table 3.3 shows the potential capacity and the location of the bores, and the total yield is highly significant respective to the lake systems.

Table 3.3: List of Bores & Associated Water

Bore	Production	Water Quality
Stephen Street	Annual Target 300 *ML*	Hardness – 182 *mg/L*
Nell E Robinson	Annual Target 120 *ML*	Hardness – 95 *mg/L*
Queens Park	Annual Target 350 *ML*	Hardness – 185 *mg/L*
Alderley Street	Annual Target 275 *ML*	Raw TH – 290 *mg/L* Treated TH < 200
Milne Bay	Annual Target 650 *ML*	MB Raw TH – 159 *mg/L* Gogg St. Raw TH – 237 *mg/L* Treated TH < 200 *mg/L*
Eastern Valley	Annual Target 700 *ML*	EV Raw TH – 159 *mg/L* Mackenzie Raw TH – 167 *mg/L* Hardness – 143 *mg/L*
Creek Street	Annual Target 200 *ML*	Hardness – 192 *mg/L*
Ballin Drive No Production	Annual Target 80 *ML*	Hardness – 110 *mg/L*
TOTAL	Annual Target 2675 *ML*	Hardness criteria changed from 150 to 200 *mg/L*(9th Aug 2004)

Source: Toowoomba City Council, WTP

3.7 External Consumers

Apart from supplying water to Toowoomba City, the water treatment plant also caters for five other local governments that receive water from the TCC water supply system:

- Cambooya Shire Council;
- Crows Nest Shire Council;
- Gatton Shire Council (limited to a small number of properties on the escarpment);
- Jondaryan Shire Council; and
- Rosalie Shire Council.

Crows Nest Shire includes the following population centres that draw water from the Toowoomba Water supply scheme:

- Crows Nest Town;
- Highfields Development Area;
- Hampton;
- Blue Mountain Heights
- Meringandan

Of the above Crows Nest Shire draws of raw water via connection to the Cressbrook/Perseverance mains near the outlet of the Pechey reservoirs. The Highfields development area also receives raw water supply to it's treatment plant via interconnection to the Cressbrook/Perseverance conveyance mains.

CHAPTER 4

LITERATURE REVIEW

4.0 LITERATURE REVIEW

4.1 Introduction

By definition, the term 'urban water demand', is usually taken to mean the amount of water required by the residential, industrial, commercial and public use on the daily, monthly or yearly basis (Billings and Jones 1996, Froukh, 2001).

4.2 Types of Water Demand

Urban water demand is highly elastic and responsive to many of the factors including, population and commercial/industrial growth trends, weather phenomena, price changes, technological influences etc (Horgan, 2003). Yoong (2003) predicted that water demand and use generally exceed greatly the minimal amounts actually required for daily needs. Urban water demand can be broken down into residential, commercial, industrial, public and losses (Yoong, 2003. and Billing and Jones, 1996).

4.2.1 Residential Use

Constitutes the major proportion of total urban use in Toowoomba (40% - 60%). The amount depends on the standard of living of the community and includes many of the daily chores such as lawn sprinkling, car washing, cooking, and ablution, filling swimming pools and drinking.

4.2.2 Commercial Use

This includes retailing outlets, offices, restaurants, hotels, hospitals etc and quantified on the basis of floor space or number of employees or both. These fluctuate according to the intensity of economic activities, and in Toowoomba's case may very greatly during times of Carnival of Flowers and major public holidays such as Easter when massive congregations take place.

4.2.3 Industrial Use

The amount varies widely depending on the type of industry. Usually food processing industries like abattoirs, dairy, poultry etc require large volumes to comply with strict food and hygiene standards.

4.2.4 Public Use

This component includes street cleaning, parks, fire-fighting, and general municipal maintenance works.

4.2.5 Losses

This is the unaccounted-for water and is the difference between supply and consumption in a region in a given period of time. The amount usually consists of leaks, overflows, evaporation, faulty metering, and other unaccounted for flows in a water supply.

4.3 Factors Affecting Water Demand

The major factors influencing urban water demand is well documented and many of the writers on the subject, Billings and Jones (1996), Bauman et al. (1998), Mays (2002) are very much in agreement. Significant impacts are imposed by factors including, population, economic cycles, and technology, weather and climate, price and conservation programs. These factors and others are discussed further in the following section (Billings and Jones, 1996).

4.3.1 Population

Population growth is often the major trend factor in water use and has a triggering effect on other sectors, such as increase in residential dwelling and hence lawns, swimming pools, car washes etc, increase in commercial and industrial of water use as well.

4.3.2 Economic Cycles

Closely inter-related and dependent to population growth is business cycle impacts, since fluctuations in industrial and commercial production rates translate into commensurate changes in water demand. As water is regarded as normal good, all other things being equal, behaves in the same manner as the economics of demand-supply trend. In other words, demand increase if the living standards increase due to higher income levels, earnings etc.

4.3.3 Technological Changes.

Technological changes can impart highly variable impact on water use patterns. The widespread increase in domestic appliances such as washing machines, dishwashers etc can increase water use. However, considerable reduction is also observed in newer dual cistern-pan systems which use half the water as previously, lawns & gardens having adopted drip irrigation technology controlled by automatic timed devices etc. New production techniques /methods in industry may use either far more or less water than previous methods, while requirements and opportunities for water re-use may dramatically cut water requirements

4.3.4 Weather and Climate

Extensive researches on the impacts weather and climate on water demand have provided conclusive evidence of impacts generated by local climate and weather patterns. Seasonal variations, especially peaking during summer is quite typical, and related to increases in outdoor activities, including lawn watering and gardening, and use of evaporative coolers. Rainfall amount and events both have been shown to significantly reduce water use patterns.

4.3.5 Price

Both water use and utility revenue are directly impacted by water rate changes and therefore important for short-, medium- and long-term forecasts. According to Billings and Jones (1996) as the relative costs of water compared to other goods drift up, perhaps due to the exhaustion and of nearby and inexpensive water supply sources or burgeoning federal water quality requirements, water price or rate effects are likely to be more noticeable.

4.3.6 Efficiency and Conservation Programs

In most municipal set-ups, water efficiency and conservation programs provide an ongoing educational service in an effort to reduce overall water consumption. However, crises resulting from prolonged drought or other supply interruptions usually generate large, albeit temporary reductions in water through restrictions, conservatory and reduction measures. These practices should be included in demand forecasts for accurate predictions to be achieved.

4.3.7 Other Factors

Physical deterioration and degradation of the water distribution and supply structure is likely to result in increased losses from leaky and broken pipes, more so in older systems. Although newer systems are not without similar problems, however, better leak detection mechanisms and gadgets, as well as less frequency of such events render it in good stead. It is therefore desirable to include estimates of future water losses in order to achieve accurate water demand forecasts.

4.4 Water Demand Forecasting

Water demand forecasting is the methodology used to predict future water needs and demand can be projected by a number of methods. Gardiner and Herrington (1986) defined forecasting methods as the procedures and conventions used to analyse past water use and to apply the resulting knowledge to the future. This leads to an emphasis that forecasting methods translate projected values of one or more of the explanatory variable such as population, residential lots, water prices, restrictions, climatic factors etc. into estimates of future water requirements.

Water demand forecasting is essential for a wide variety of reasons and for several different agencies for numerous planning studies, production planning and optimisation strategies and requirements. Water demand forecasting can be of two types: long-term forecasting and short-term forecasting. According to several researchers including Jain et al. (2001) long-term forecasting is useful in planning and design, and making extension plans for an existing water system, while short-term forecasting is useful in efficient operation and management of an existing system.

Following is an summary of the types of forecasting together with their application and benefits adopted from USACOE (1988), Billing and Jones (1996), Froukh (2001), and Jain et al. (2001).

4.4.1 Long-Term Forecasting

The challenge imposed by long-term forecasting is a direct result from the increasing difficulty of predicting events more and more distant from the present, usually for duration of 10 years and more. Forecast errors increase with increasing length of forecasting period as the uncertainty pertaining to many of the principle variables becomes hypothetical. However, long-term forecasts play an important role, even more so for the following reasons:

- Incorporating new supply source(s) for future expansion;
- Capital infrastructure expansions, i.e. new dams, mains etc.
- Capacity planning.

Accurate long-term forecasting is imperative because an overbuilt facility can become burdensome as water rates and charges will have to be increased. On the other hand, water shortages from inadequate raw water acquisition, treatment, or storage facilities impose debilitating effect and cost to customers.

4.4.2 Medium-Term Forecasting

Varied forecasting of durations anywhere between 1 to 10 years are classified as medium-term and are commonly developed for the following reasons:

- Planning improvements to distribution and supply systems;
- Implementing technological changes and improvements in water treatment systems;
- Reviewing and setting of water rates and charges.

4.4.3 Short-Term Forecasting

Short-term forecasting durations are diverse and can range from minutes, hours, daily, weekly, monthly, seasonal, bi-annual and annual. Since the factors affecting water demand can be predicted with reasonable confidence, highly accurate forecasts can generally be developed. These are useful for a multitude of operational and design purposes including:

- Designing of distribution reservoirs and network;
- Production optimisation and pumping regimes/scheduling;
- Routine maintenance works etc;
- Drought contingency plans;

4.5 Demand Forecasting Methods

Forecasting methods are either based on an analytical or mathematical approach while others, mainly for short-term forecasting, use a purely heuristic approach (Rahman and Bhatnagar, 1988). Subsequently, some researchers have attempted to integrate both mathematical and heuristic approaches for short-term water-demand forecasts (Hartley and Powell, 1991). According to Billings and Jones (1996) forecasting methods can be described using per-capita and unit use coefficient approaches, end-use models, extrapolation and structural and causal models. Froukh (2001) has listed several methods that are currently in use as follows:

- Time-extrapolation;
- Disaggregate end-users;
- Single-coefficient method;
- Multiple-coefficient method;
- Probabilistic method;
- Memory-based learning technique;
- Time-series models such as Box Jenkins and ARIMA models;
- Neural Network.

4.5.1 Per-Capita and Unit Use Coefficient Methods

Per-capita method was the most widely used systems of the past for urban water use. While it could be applied to disaggregate water use (residential water use), the method is almost always used to explain aggregate use for an urban area (Baumann, et. al. 1997). The per capita method assumes that a single explanatory variable provides an adequate explanation of water use. Other variables are assumed to be unimportant or perfectly correlated with the variable being utilised. This alone renders the per capita method unreliable as single variable trends and relationships are inadequate for forecasting albeit for very rough estimates.

Unit use Coefficient method, not withstanding the weaknesses of the per capita method, is useful in the context of disaggregate forecasts (Baumann, et. al., 1997). As water use is broken down into sectors or categories like residential, industrial, commercial etc it becomes apparent that water use in each of these can be explained by single but different variables.

4.5.2 End-Use Models

End-use model forecasts use extensive detailed information about customer behaviour (Billings and Jones, 1996). They build up a forecast from data on inventory of water using appliances and fixture and typical patterns of behaviour. However, the use is limited because of excessive and extensive data requirements.

4.5.3 Extrapolation

Extrapolation encompasses a variety of techniques, including simple time series trends, exponential smoothing, and Box-Jenkins (autoregressive integrated moving average i.e. ARMA or ARIMA) models to project historic water use trends into the future (Billings and Jones, 1996).

4.5.3a Time-Series

A time series is a chronological sequence of observations on a particular variable. According to Cryer (1986) the purpose of time-series analysis is to understand the stochastic mechanism that gives rise to an observed series, and to predict future events or values of that series. The method allows for observations to be made at a continuous time series at regular intervals, or be aggregations of discrete events (Fleming, 1994). The nature of time series forecasting maybe quantitative or qualitative.

4.5.3b Box-Jenkins ARMA/ARIMA Models

The Box-Jenkins methodology develops a time series model for use in forecasting based on a iterative procedure of identification, estimation and diagnostic checking (Fleming, 1994). Once a time series model has been developed, it can be used as a forecasting tool to generate predictions of future values of the time series. Advantages of Box-Jenkins methodology is that it uses dependency in the observations to produce accurate results and offers a more systematic approach to building, analysing and forecasting (Billing and Jones, 1996).

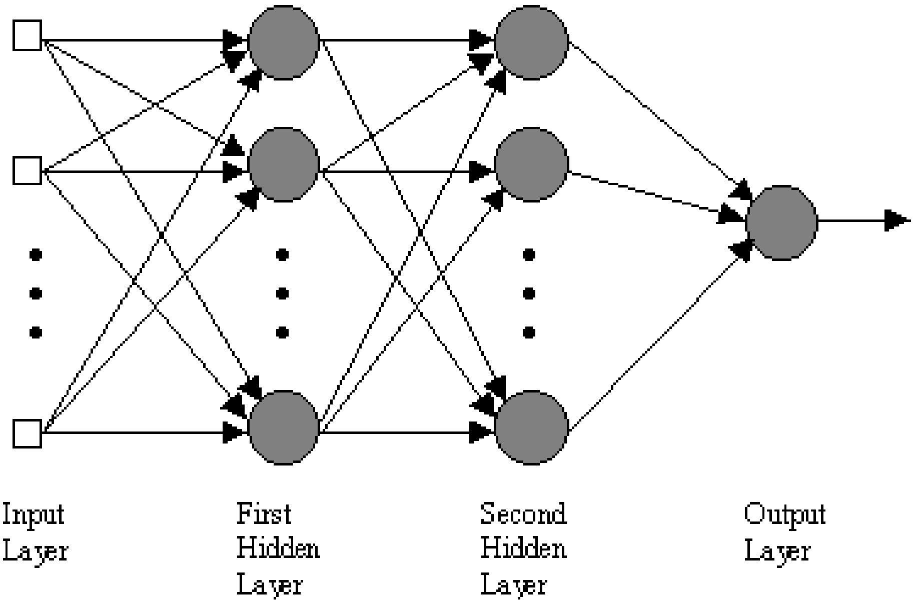
4.5.4 Regression Techniques

Regression techniques fall under causal or multivariate models as a variety of factors affecting water use can be used together in a forecasting model. The technique can be applied with single coefficient and also provides the flexibility of using numerous independent variables that is related to water use. Multi-variable analysis is further applicable in trends not only in linear, but curvilinear, exponential, logarithmic, hence provides reasonable accuracy to its prediction capability. However, it should be noted that regressive techniques are averaging in nature of its prediction which, tends to smooth out the extremities of real situations.

4.5.5 Artificial Neural Networks (ANNs)

Artificial Neural Networks are mathematical models of theorized mind and brain activity, which attempt to exploit the massively parallel local processing and distributed storage properties believed to exist in the human brain (Zurada, 1992). According to Jain et. al. (2001), the ANN technique, also called parallel distributed processing, has received a great deal of attention as a tool of computation by many researchers and scientists. It highlighted one of the important characteristics of ANN is it's ability to learn from facts or input data and the associated output data. Figure 4.1 shows a schematic of a simple structure of an artificial neural network.

Figure 4.1: Basic Structure of an Artificial Neural Network



Source: Neurosolutions.com

4.6 Applicable Literature

Past Australian experience has shown that per-capita/end-use combined with simple regression was widely used in most water supply centres, both for long and short-term demand forecasting (Gallagher et al. 1981). This was been mainly attributed to unreliable and incomplete data availability and respectively lesser research emphasis placed on the importance of forecasting. However, since then with realisation of the importance of accurate water demand forecasts and more importantly accurate and reliable databases available, water managers have opted for combination of time series and multi-variate regression and neural networks for their forecasting needs.

Newcastle's water consumption was developed by Vishwanath (1991) using the Recursive Least Squares Model for durations of less than three days based on temperature and rainfall inputs. Draper (1994) investigated annual water demand for the Perth Metropolitan Area for 33 years till 1990/91, using econometric time-series evaluation and using explanatory variables such as effects of marginal price changes on water consumption behaviour. Similarly Horgan (2003) created a model to predict effectiveness of advertising campaigns and water restrictions on Perth's water usage using multivariable regression techniques to explain the variables. The results showed variable results with some campaigns increasing water use and others decreasing water use, however, introduction of stricter restrictions was extremely effective in reducing water demand.

Considerable work has been done in Adelaide to develop demand forecasting models. Dandy's (1987) study revealed conclusively that climatic factors such as rainfall, temperature and evaporation and other factors influence water demand. Davies and Dandy (1995) later built on earlier work on Dandy (1987) to add variables such as price, socio-economic and physical variables to the model. Regression analysis was used to model residential water demand for the city of Adelaide for a discrete sample of households for a 13 year period. Models were developed using a dummy intercept to model consumption and it was shown that price and rate structure are significant in determining the level of water demand. Other factors such as property value and household size were also shown to be significant determinants.

Fleming (1994) used multiple linear regression, time-series methods and artificial neural networks (ANN) for the prediction of per-capita water consumption on the Northern Adelaide Plains using variables such as month of the year, rainfall, evaporation, number of wet days per month and real price of water. The study revealed the ANNs produced superior results to regression and time-series modelling, however, seasonal and short-tem patterns have been predicted equally well by both simple and statistically sophisticated methods. Significant variables in the prediction of per capita consumption were found to be the month of the year and rainfall in the current and previous month, signifying that rainfall events are equally important.

Zhou et al (2000) has used a time-series model formulated as a set of equation representing the effects of four facts on water use namely, trend, seasonality, climatic correlation and autocorrelation for Melbourne. Zhou et al.(2002) later developed a time-series forecasting model of hourly water consumption 24 hours in advance for an urban zone within Melbourne using similar sets of equations. Zhou et al. (2002) quite importantly observed that in the past Australian application reveals the development of statistical models, typically multiple regression and time-series for predicting urban water demand. Weeks and McMahon (1973) in Zhou et al. (2002) also stressed that the number of rainy days per annum was the most significant climatic variable affecting annual per capita use.

Similarly, Jain et al (2001) compared the use of ANN, multiple regression and time-series models forecast short-term water demand in Kanpur, India. The study revealed that water demand was very much driven by the maximum air temperature and interrupted by rainfall occurrences. More importantly, it agreed with Weeks and McMahon (1973) and Zhou et al. (2002) that rainfall occurrences rather than amount itself better correlated with water demand trends.

In addition, extensive work has been done in the field of water demand forecasting and particularly short-term forecasting by Fildes et al. (1997), Zhou, et. al (2001), Bougadis, et al. (2005), Aly and Wanakule (2004) and Alvisi et al (2003). Most literature reveals that although newer forecasting and modelling system such as ANN are used giving quite comprehensive and sophisticated analysis, regression and time series techniques remain the most applied of the forecasting tools because of it’s simplicity, degree of accuracy and data requirements.

CHAPTER 5

METHODOLOGY

5.0 METHODOLOGY

The forecasting models discussed in the literature review with the exception of per-capita, end-use and ANNs use some form of regression analysis. According to Levine et al. (1999) regression analysis is a statistical technique that defines the relationship of one dependent variable (water demand) with one or more independent variable (population, climate, tariffs) as means of viewing and statistically explaining the relationships that exist between them. In selecting the method to be employed for this particular application, it is necessary to consider the following basic criteria:

- The accuracy of the forecasting required;
- The cost of data acquisition and analysis;
- The time-frame available to carry out modelling and simulation.

The methodology most suited for the need at hand is based upon the software that the sponsor uses and currently has most of its databases on. The statistical package should be readily available and support the required analysis, ***Multiple Variable Regression Analysis*** to be carried out with reasonable accuracy and reliability. The secondary issue of concern would be the duplication of the analysis in the near future without high purchasing expenditure into upgraded versions of the software and hiring of skilled and expensive personnel for operation purposes. As a result of above selection criteria *Multiple Variable Linear Regression Analysis* was chosen as the preferred methodology and an EXCEL based software for particular application was used.

5.1 Multiple Variable Regression Analysis

Multiple regression is extension of simple regression analysis which enables analysis of relationships between a dependent variable and two or more explanatory variables (Kenkel, 1996). The strength of the analysis lies in the fact that a multitude of analysis can be carried out depending on the nature of relationship and trends between the dependent and explanatory variables.

These include linear regression models, curvilinear, exponential, logarithmic trends. The two most common models utilised are described below with the aid of equations for better understanding.

5.1.1 Multi-Variable Linear Regression Model

$$\mathbf{Y}_i = \beta_0 + \beta_1 \mathbf{X}_{1i} + \beta_2 \mathbf{X}_{2i} + \ldots\ldots + \beta_J \mathbf{X}_{Ji} + \epsilon_i \qquad \textbf{(5.1)}$$

Where:

β_0 = Y intercept

β_1 = Slope of Y with Variable X_1 holding variables X_2, X_3 .....X_J

β_2 = Slope of Y with Variable X_2 holding variables X_1, X_3 .....X_J

β_J = Slope of Y with Variable X_2 holding variables X_1, X_3 .....X_{J-1}

ϵ_i = Random error in Y for observations *i*

5.1.2 Multi-Variable Curvilinear Regression Model

$$\mathbf{Y}_i = \beta_0 + \beta_1 \mathbf{X}_{1i} + \beta_2 \mathbf{X}^2_{1i} + \epsilon_i \qquad \textbf{(5.2)}$$

Where:

β_0 = Y intercept

β_1 = Coefficient of the linear effect on Y

β_2 = Coefficient of the curvilinear effect on Y

ϵ_i = Random error in Y for observations *i*

5.2 Model Selection

For the purpose of this study, multi-variable linear regression models will be developed for daily peak demand and weekly peak demand using the following basic general equations:

$$\mathbf{Y}_i = \beta_0 + \beta_{ni} (\mathit{Variable}_1 + \ldots\ldots + \mathit{Variable}_n)_i + \epsilon_i \qquad \textbf{(5.3)}$$

Where:

β_0 = Y-intercept

β_{ni} = Slope of Y with Variable$_{1\text{-}j}$ holding other variables

ϵ_i = Random error in Y for observations i

A total of 61 (see Appendix E) combinations of preliminary Trial Models were tested for model selection and from that 16 models were chosen for presentation in the study and to reveal the trends and relationships that were apparent in the preliminary Trial models. Specific analysis will take into consideration daily Peak Demand (D_t) as a function of past average daily consumption (D_{t-1}), average maximum temperature (T_t), and daily rainfall (R_t), giving rise to principal equation below:

$$\mathbf{D}_t = \beta_0 + \beta_1 \mathbf{D}_{t-1} + \beta_2 \mathbf{T}_t + \beta_3 \mathbf{R}_t + \epsilon_i \qquad \textbf{(5.4)}$$

5.3 Data Requirements

The preliminary trial models were run with continuous data available for the duration of 10 years, from 1995 - 2004. However, it was observed from the data quality analysis phase that demand data prior to year 2000 inclusive was inconsistent with the plant capacity and therefore the final modelling was carried out using continuous daily data from year 2001 to 2004 only.

5.4 Variables Tested

Variables used in the preliminary investigation were:

i. Temperature (Temp)
ii. Rainfall
iii. Raindays (Binary input i.e. 0 = No Rain Event; 1 = Rain Event)
iv. Moving Average Demand (MAD)
v. Previous Day Consumption (D_{t-1})
vi. 4 Day Weighted Average Demand (4dWAD)

vii. 7 Day Weighted Average Demand (7dWAD)

viii. Restrictions (Restrict)

Sixteen (16) models of differing variable combinations (*Appendix E*) was used to determine the strength of variables on demand and further 9 models were investigated with added variables as listed below:

i. Deviation of maximum temperature from the mean (Temp. Dev.)

ii. Temperature difference of maximum and minimum (Temp. Diff.)

iii. Rainfall Weightings (RW)

Table 5.1 below showed the criteria used to arrive at the rainfall weightings used in the analysis. The rainfall weightings were derived from visual inspection of the demand trends in relation to rainfall event and amount. This variable was purely experimental and statistically sound method of rainfall weighting should be incorporated for future studies.

Table 5.1: Criteria for Rainfall Weightings

Rainfall Description	Rainfall Range (mm)	Weightings Awarded
Nil	0	0
Drizzle	$0 < R < 1$	0
Light	$4 \leq R \leq 1$	1
Medium	$10 \leq R < 4$	2
Heavy	$R > 10$	3

5.5 Statistical Measures and Tests on Model

The Multi-Variable Linear Regression Analysis software uses standard statistical tests to determine the significance of the analysis, including the multiple coefficient of determination, more commonly known as R^2 and adjusted R^2. The F-test provides for variance or degree of diversity of the variables, and larger values show that variables are unique in its relation to demand. The Durban-Watson determines the correlation effect of variables used in the forecasting process.

5.5.1 Coefficient of Determination

Coefficient of Determination or simply R^2 is a common measure of 'goodness of fit' of a regression model. It is derived from the decomposition of the total variation in the dependent variable (*SST*) into two components:

i. the variation in *Y* (*demand in this case*) that can be explained by the sample regression equation, denoted by *SSR* and;

ii. the variation in *Y* that cannot be explained by the sample regression equation, denoted by *SSE*.

The total variation *SST* is decomposed into the explained variation SSR and the unexplained variation *SSE* such that;

$$\sum \left(y_i - \overline{y}\right)^2 = \sum \left(\hat{y}_i - \overline{y}\right)^2 + \sum \hat{e}_i^2 \qquad \textbf{(5.5)}$$

or

$$\boldsymbol{SST} = \boldsymbol{SSR} + \boldsymbol{SSE} \qquad \textbf{(5.6)}$$

where:

$SST =$ Total Sum of Squares $= \sum \left(y_i - \overline{y}\right)^2 = \sum y_i^2 - n\overline{y}^2$

$SSR =$ Regression Sum of Squares $= \sum \left(\hat{y}_i - \overline{y}\right)^2$

$SSE =$ Residual Sum of Errors $= \sum \hat{e}_i^2$

The Coefficient of multiple determination is calculated in the software package using the following formula:

$$R^2 = \frac{SSR}{SST} = 1 - \frac{SSE}{SST} \qquad \textbf{(5.7)}$$

The coefficient of multiple determination measures the proportion of variation in the dependent variable that is explained by the independent variables and it must be lie in between 0 and unity.

$$\mathbf{0 \leq R^2 \geq 1} \qquad \textbf{(5.8)}$$

Values of R^2 closer to 1 indicated that the independent variables explain most of the variations in Y and the sample data tend to lie near the estimated regression equation.

5.5.2 Adjusted Coefficient of Determination ($\overline{R}^2$)

This measure of goodness of fit takes into account the number of explanatory variables included in an predictive model and is given by the formula:

$$\overline{R}^2 = \frac{\dfrac{1 - SSE}{(n - K - 1)}}{\dfrac{SST}{(n - 1)}} \qquad \textbf{(5.9)}$$

where:

n = number of observations

K = number of variables

All other terms as previously defined.

5.5.3 Model Hypothesis Test

The Multiple Variable Linear Regression Analysis software uses the F-Statistic to test the acceptability of the model. The F-test is a measure of degree of diversity in the variables or variable variances and is given as a single value F-Statistic. Since F-statistic is the ratio of observed sample variances, and is dependent upon the number of variables and the number of observations used in the analysis.

The F-test is used since multiple variables are used and these needs to be jointly tested simultaneously as opposed to t-test which tests single coefficient at a time and then moves to the next coefficient in the regression. The F-statistic is given by:

$$F = \frac{\frac{SSR}{K}}{\frac{SSE}{(n - K - 1)}} \tag{5.10}$$

The critical-F-statistic provides for rejection of the model given that:

$$F\text{-Statistic} < \text{Critical-}F\text{-Statistic} \tag{5.11}$$

For this application, as F-statistic is greater than critical-F-statistic, the model can be accepted at 95% confidence level.

5.5.4 Estimated Standard Error of Regression

The estimation standard error of regression, denoted by S_e is an estimate of σ_e, the standard deviation of the error terms, and is simply the square root of S_e^2 and given by the following equation:

$$S_e = \sqrt{\frac{SSE}{n - K - 1}} \qquad \textbf{(5.12)}$$

NB: All terms as previously defined

5.5.5 Durban-Watson Statistic

The Durban-Watson statistic is most often used test for the presence of serially correlated error terms or simply diversity between the variables used in the model. The software uses Durban-Watson statistic, *d*, which is defined as follows:

$$d = \frac{\sum_{t=1}^{n} (\hat{e}_t - \hat{e}_{t-1})^2}{\sum_{t=1}^{n} \hat{e}_t^2} \qquad \textbf{(5.13)}$$

Ideally the value of *d* must lie between 0 and 4, with values of d near 2 supporting null hypothesis of no serial correlation, values near 0 indicating positive serial correlation, and values near 4 indicating negative serial correlation.

CHAPTER 6

RESULTS

6.0 RESULTS

The selected combination of models *(see Appendix F)* were run with 4 years of aggregated continuous data and the full results are provided in Appendix I.1-9 and the model parameters in Appendix H. Nine models were selected based on final regression modelling results, in particular the goodness of fit, R^2, adjusted R^2, standard error as well as F- and critical F-Statistic. The table below summarize the results of the selected 9 models that are used to simulate the behaviour of the forecasted demand compared to the actual demand trend.

Table 6.1: Selected Models for Simulation

Statistical Measure	R^2	Adj. R^2	Standard Error	F – Statistic	Durban Watson Statistic	Critical F – Statistic
MODEL – 3	0.74	0.74	3.49	1384	1.93	2.61
MODEL – 5	0.74	0.74	3.47	1405	1.47	2.61
MODEL – 8	0.75	0.75	3.45	1074	1.98	2.37
MODEL – 9	0.75	0.75	3.46	859	1.98	2.22
MODEL – 12	0.76	0.76	3.35	1159	1.68	2.37
MODEL – 13	0.76	0.76	3.35	930	1.66	2.22
MODEL – 21	0.74	0.74	3.51	1032	1.99	2.37
MODEL – 22	0.74	0.74	3.48	1056	2.06	2.37
MODEL – 25	0.75	0.75	3.46	613	2.05	2.01

Although the coefficient of determination on the models ranged from 0.21 to 0.76, it must be noted that some models with lower R^2 were chosen for comparison purpose and is by design. It also should be duly noted that the majority of the models show higher R^2 ranging from 0.6 – 0.76. The other selection factor was the low error values; mostly less than 8% is another indication of reliability of the dataset used.

Also of great importance is the result of the model parameters or coefficients of variables used in the selection of model for simulation as well. A summary of variable coefficients as used in modelling and simulation equation is given in Table 6.2 below, and the rest of the coefficients are provided in appendix H for further reference.

Table 6.2: Variable Coefficients and Simulation Equation

Model Number	Coefficients and Simulation Equation
MODEL – 3	D = -1.93 + 0.11*Temperature – 0.1*Rainfall + 0.99*MAD
MODEL – 5	D = 0.90 + 0.17*Temperature – 0.17*Rainfall + 0.89*4dWAD
MODEL – 8	D = - 0.48 + 0.11*Temperature – 0.06*Rainfall – 1.5*Rain-days + 0.96*MAD
MODEL – 9	D = - 0.37 + 0.11*Temperature – 0.07*Rainfall – 1.5*Rain-days + 0.96*MAD – 0.04*Restriction
MODEL – 12	D = 2.72 + 0.16*Temperature – 0.1*Rainfall – 2.42*Rain-days + 0.86*4dWAD
MODEL – 13	D = 3.58 + 0.17*Temperature – 0.10*Rainfall – 2.41*Rain-days + 0.85*4dWAD – 0.33*Restriction
MODEL – 21	D = - 0.60 – 1.91*Rain-days + 1.02*MAD + 0.13*Restriction + 0.02*Temperature Difference
MODEL – 22	D = - 0.60 + 0.11*Temperature + 1.02*MAD + 0.00*Restriction – 1.05*Rainfall-Weightings
MODEL – 25	D = - 0.46 + 0.11*Temperature –1.26*Rain-days + 0.97*MAD + 0.01*Restriction + 0.15*Temperature Deviation + 0.11*Temperature-Difference – 0.68*Rainfall-Weightings

NB: All the variables are self explanatory and provided for in the previous chapter.

6.1 Model Simulation and Behaviour

The nine model equations stated in table 6.2 were used to simulate the behaviour of the forecasted demand in relation to the actual demand and these are shown in the figures following this together with the error between the actual and forecasted demand. It is desirable to over-predict marginally than to run out of water during any part of the day and principally to avoid pumping at peak hours, repercussion of which are discussed in the following chapter.

Figure 6.1: Model 3 Simulation of Actual and Forecasted Demand for Year 2004

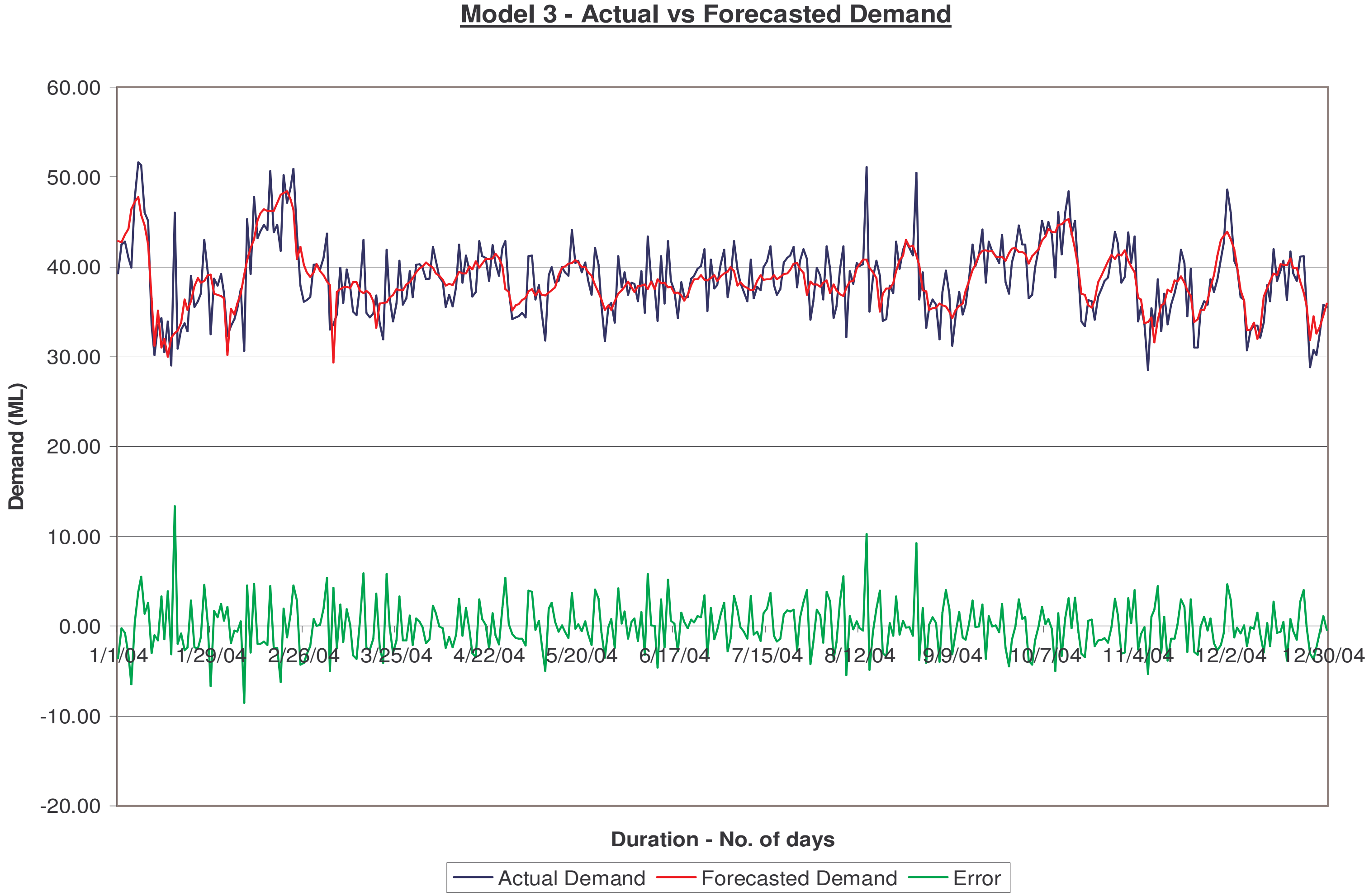


Figure 6.2: Model 5 Simulation of Actual and Forecasted Demand for Year 2004

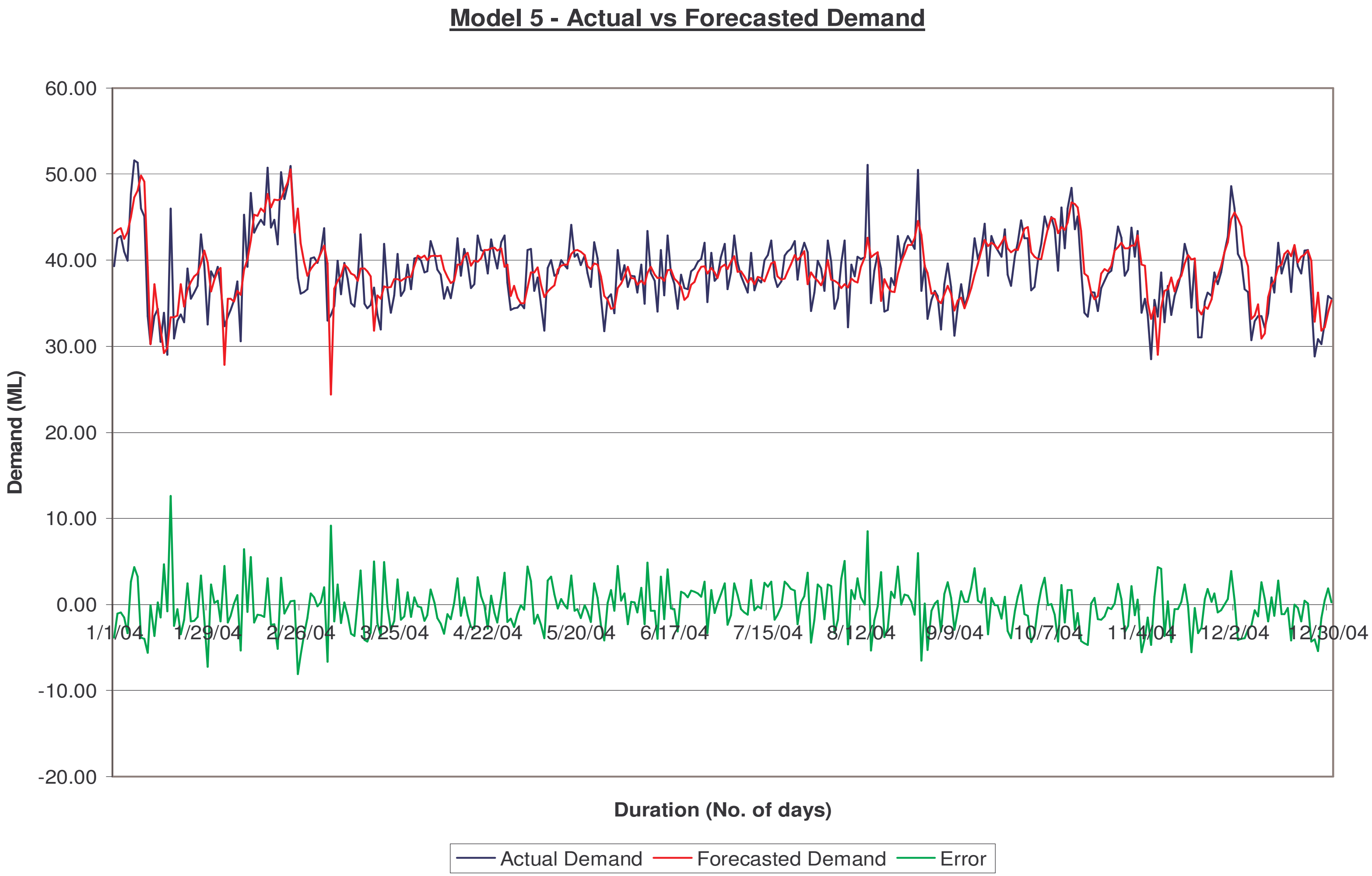


Figure 6.3: Model 8 Simulation of Actual and Forecasted Demand for Year 2004

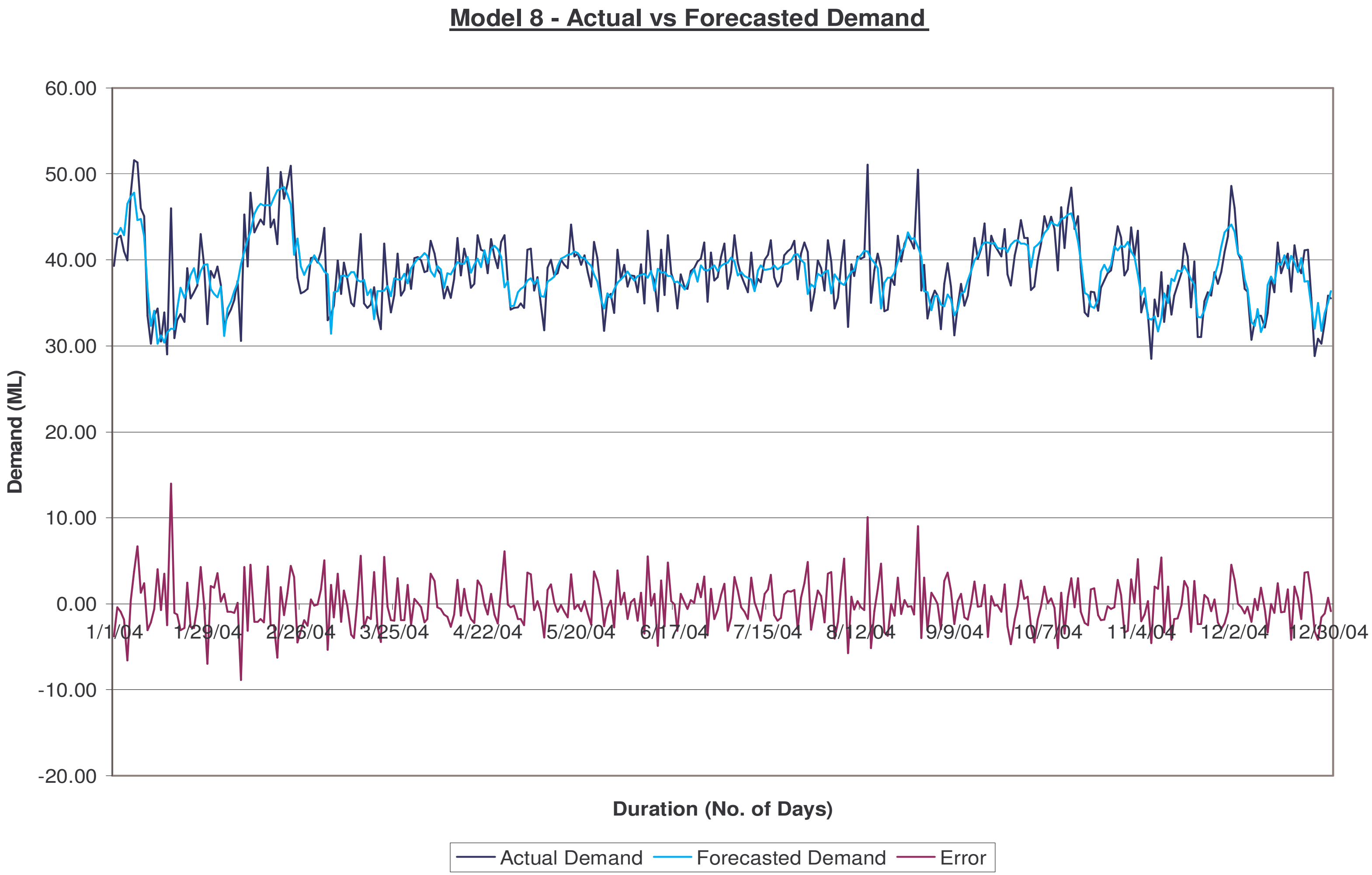


Figure 6.4: Model 9 Simulation of Actual and Forecasted Demand for Year 2004

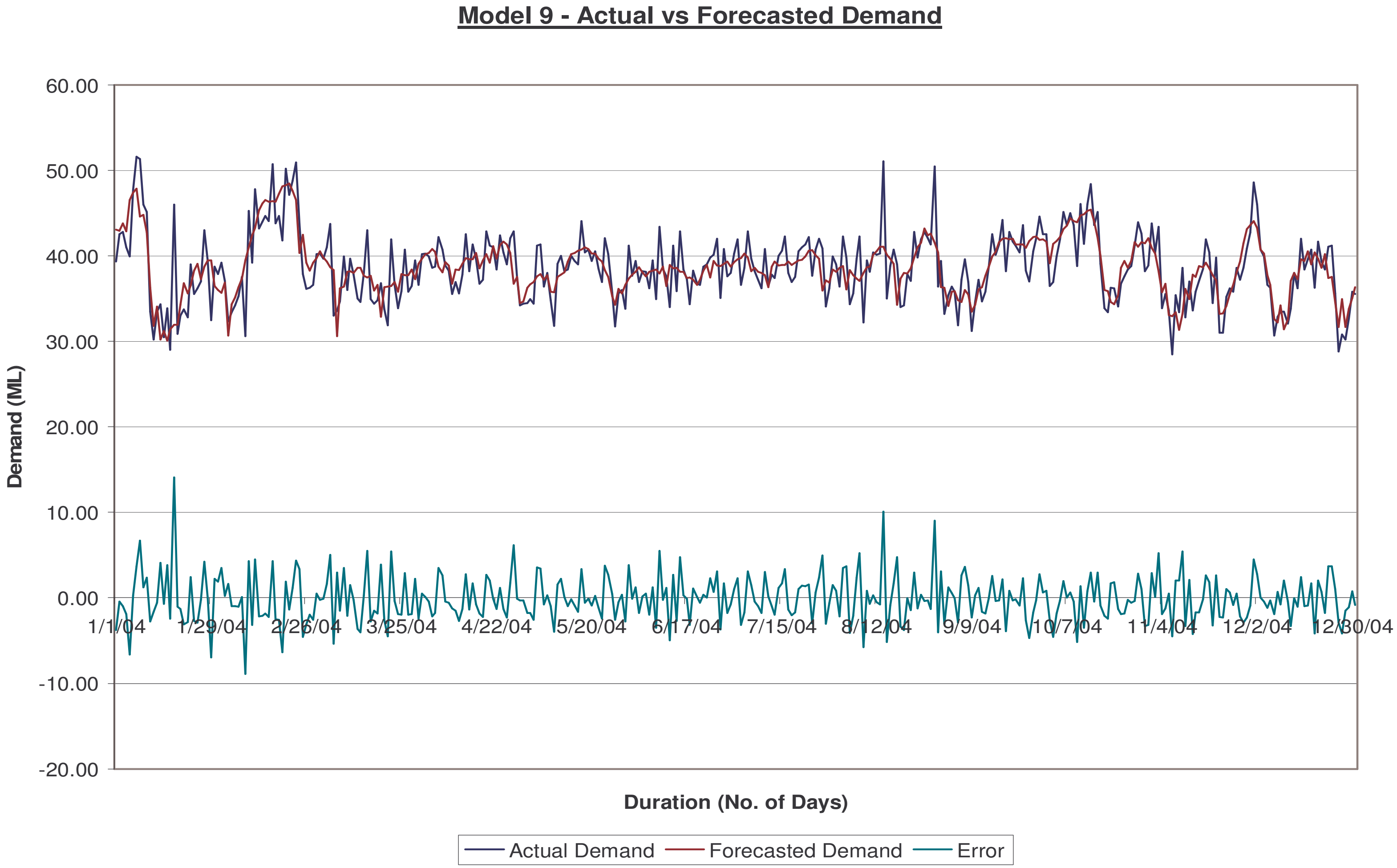


Figure 6.5: Model 12 Simulation of Actual and Forecasted Demand for Year 2004

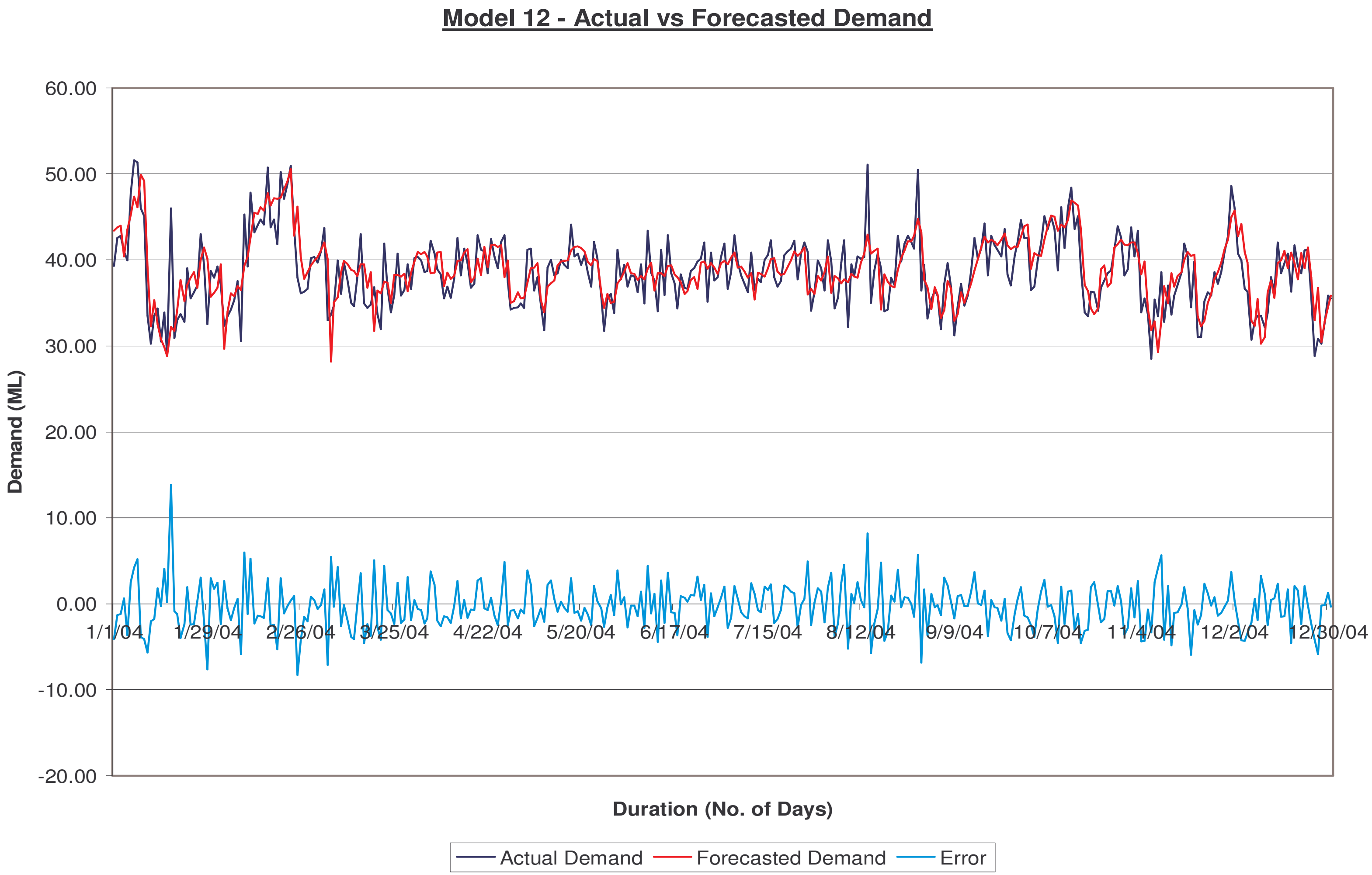


Figure 6.6: Model 13 Simulation of Actual and Forecasted Demand for Year 2004

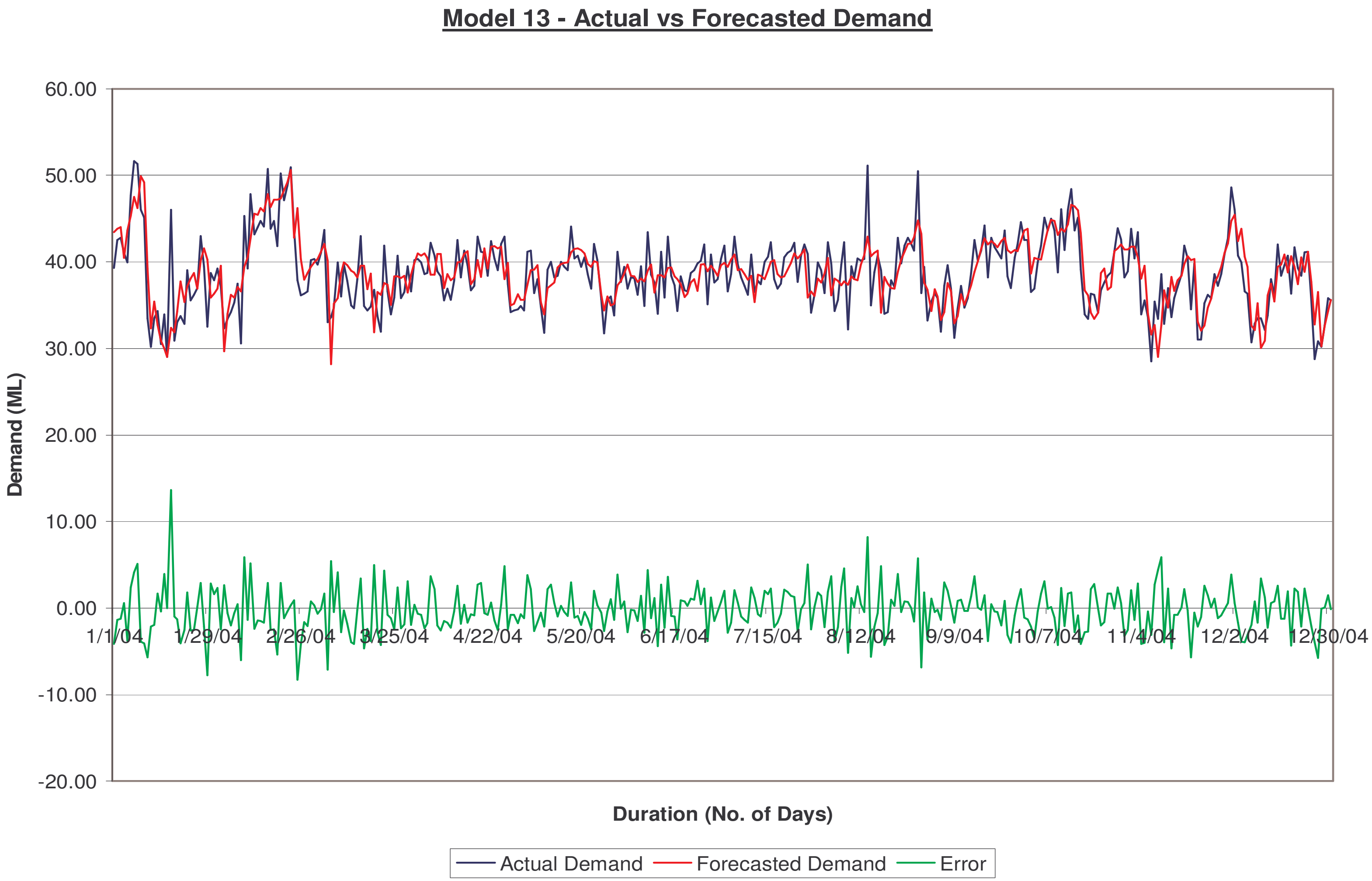


Figure 6.7: Model 21 Simulation of Actual and Forecasted Demand for Year 2004

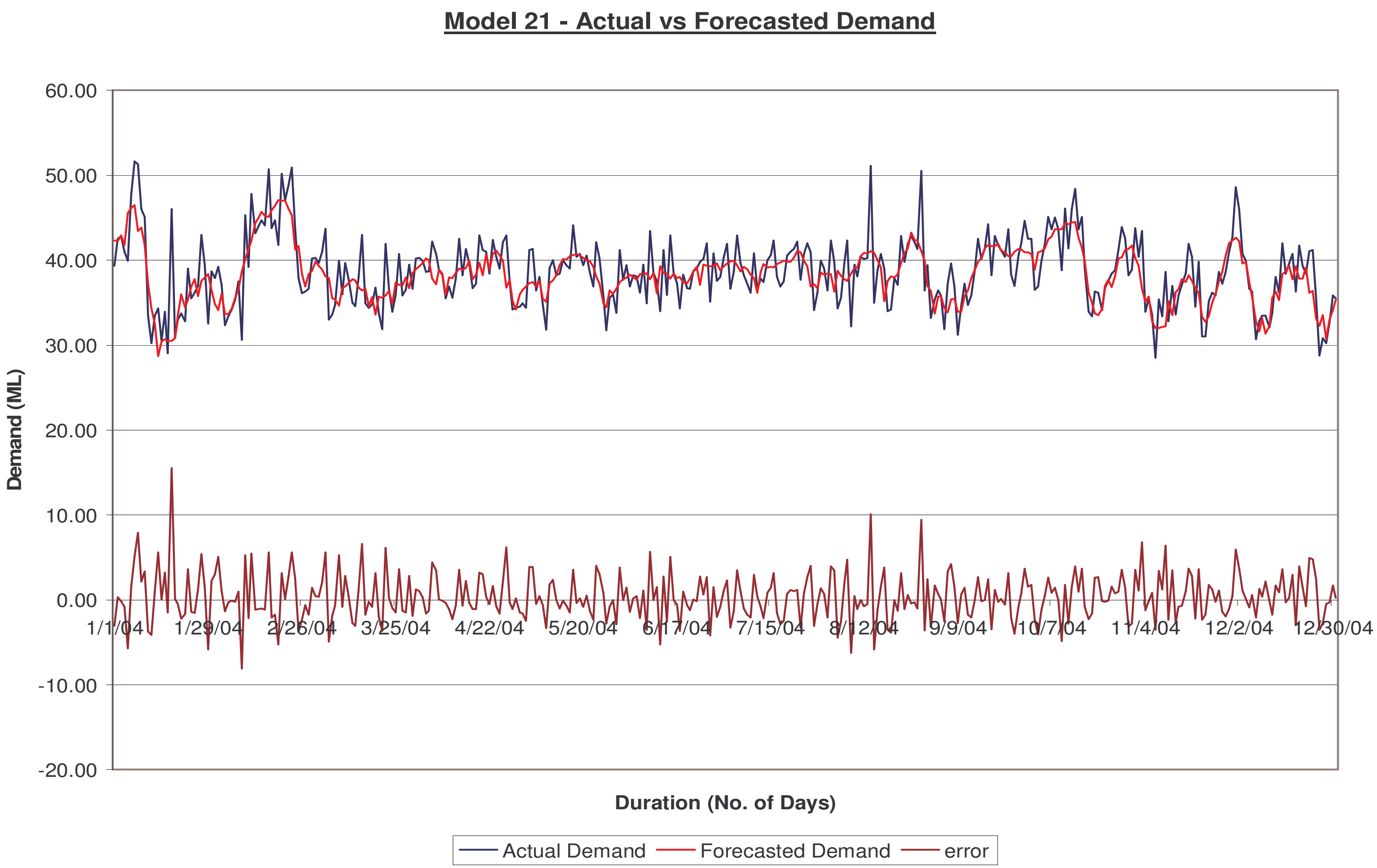


Figure 6.8: Model 22 Simulation of Actual and Forecasted Demand for Year 2004

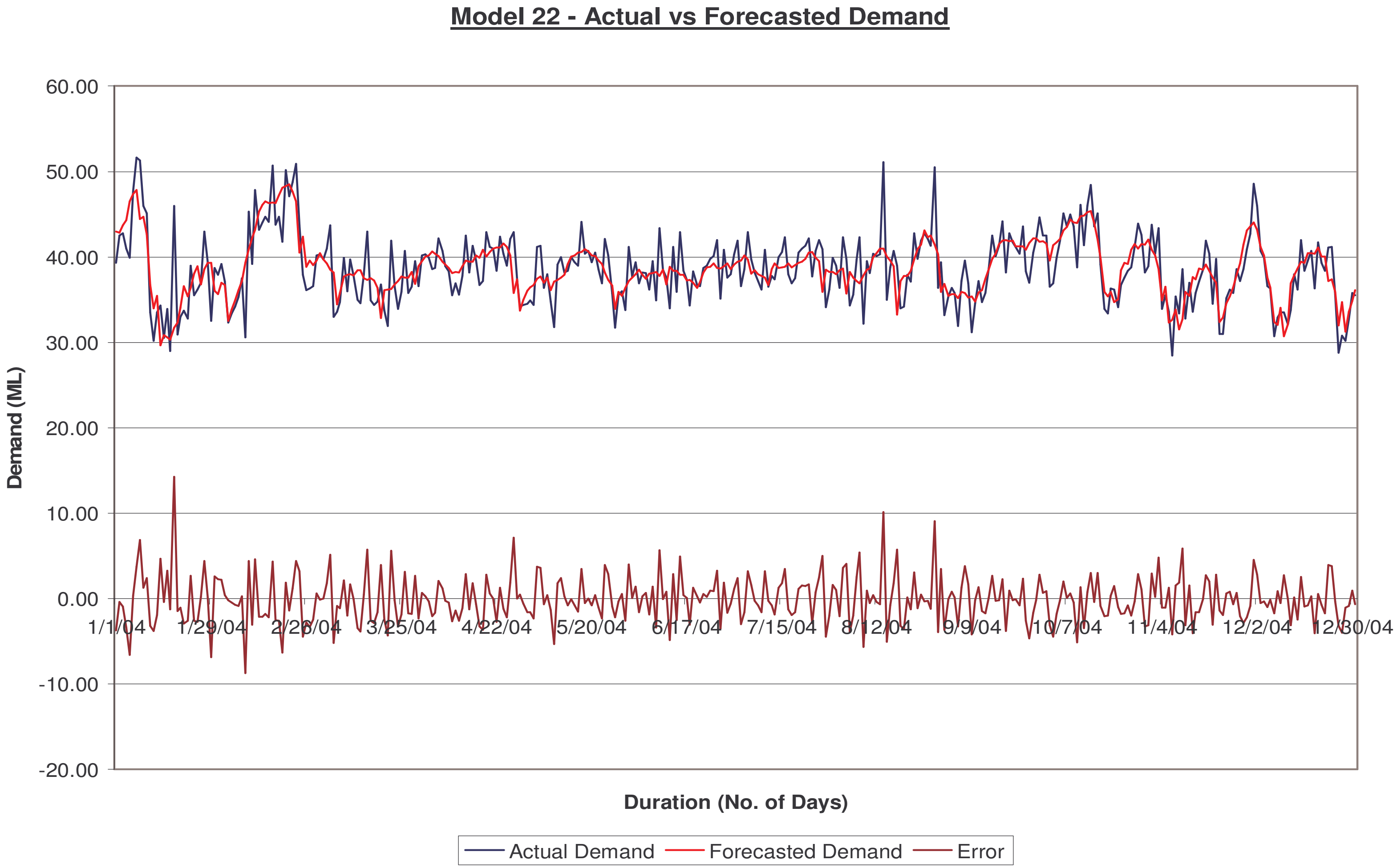
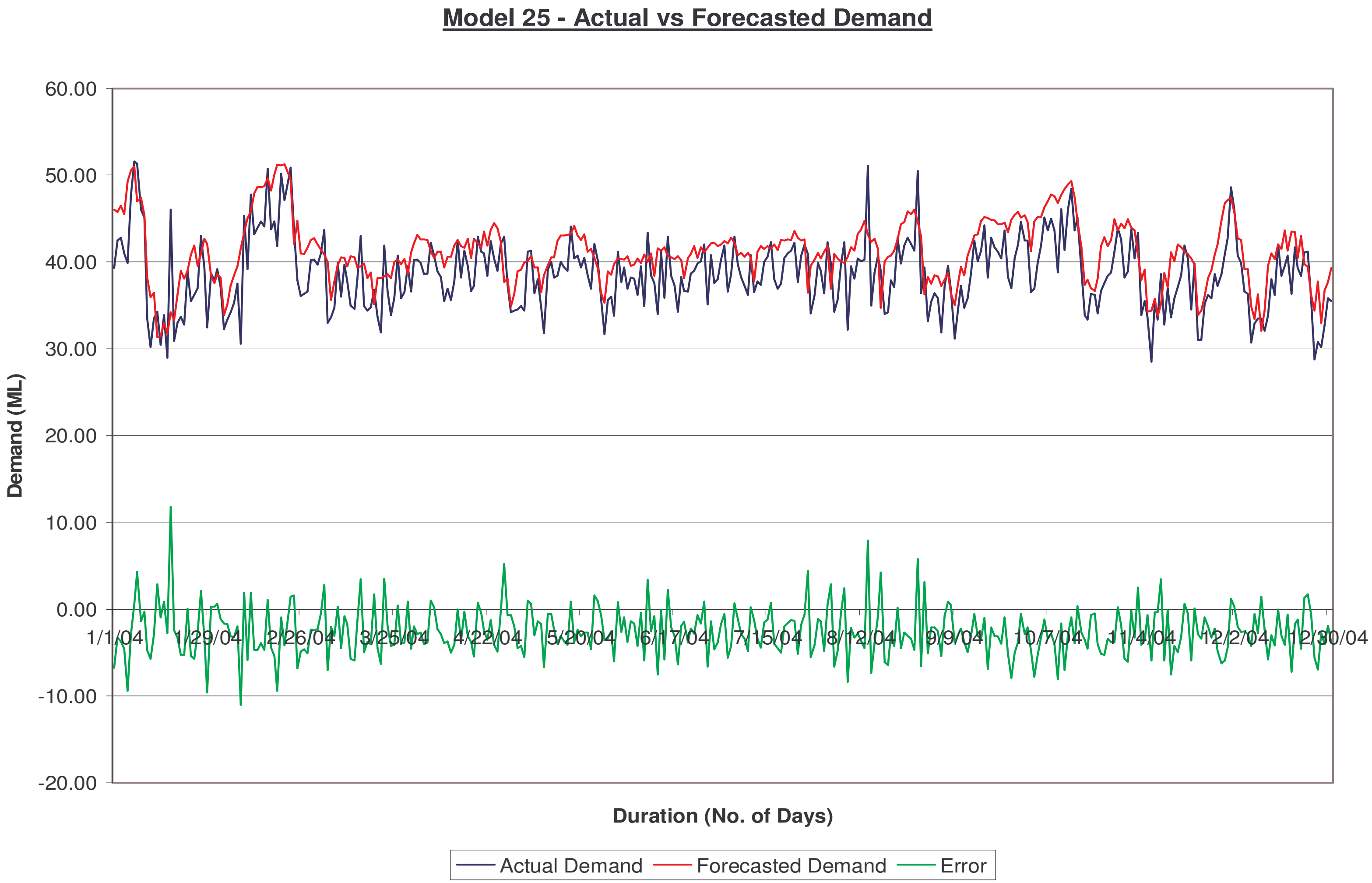


Figure 6.9: Model 25 Simulation of Actual and Forecasted Demand for Year 2004



CHAPTER 7

DISCUSSION AND RECOMMENDATIONS

7.0 DISCUSSION AND RECOMMENDATIONS

7.1 Variable Strength of Selected Models

The final models selected in the previous section were primarily based on the its goodness of fit, correlation of the variables as well as minimum standard errors. As shown in the results table in appendix G, it works out that the least errors were contained in Model 12 and 13, and these models also happen to have the best goodness of fit as well. However, other models with differing R^2 were selected for the purposes of discussion and comparison on the variable strength and its combined effectiveness in predicting Toowoomba's demand. Each of variables used in the models are discussed in the following section in relation to its individual strength as well as the combined strength with other variables.

7.1.1 Temperature Variables

Three sets of temperature variations were investigated including the commonly used maximum air temperature, together with new variables, deviation of maximum temperature from the mean as well as the temperature difference between the maximum and minimum air temperatures. Maximum temperature provided the strongest variable coefficient variables of the three, with coefficients going as high as 0.62 resulting in actual demand of 15.5ML/d on a given temperature of 25℃. In the selected models the maximum temperature coefficient ranged from 0.11 – 0.17 resulting in equivalent demand of 2.75 – 4.25 ML/d on the above stated temperature.

The temperature difference also showed close trend relation similar to the trend of maximum temperature, however, as it takes account of the minimum temperature as well as the maximum temperature, the results vary accordingly. For higher extreme demand prediction maximum temperature is ideal and for overall demand prediction, temperature difference will give a better result as shown as it has greater influence on both extremes of the temperature.

7.1.2 Rainfall, Rain-days and Rainfall Weight

Rainfall is the next principal factor on Toowoomba's water demand. However, the effect of rainfall in demand is only observed in medium to heavy rainfall events which make the number of rain events fed as binary input in the model as zeros and ones for nil rainfall and rainfall events respectively, quite telling in its predictive strength. In many models the strength of rain-days are as high as -4.69, implying that any rainfall event in prediction would reduce the forecasted demand by the same margin, which can be excessive for minor rainfall events.

This observation prompted an experimental variable, Rainfall-Weightings to be used, so that reasonable weightings would justify the trend pattern in regards not only to rainfall event but also to rainfall amount. Hence, an attempt was made, within reasonable means to combine both the rainfall amount and event into a single variable. For the rainfall weightings criteria is given in Table 5.1 in the previous section. The coefficient for this variable in accepted model ranges from -0.68 to 1.05, which in rainfall weightings terms mean that a heavy rainfall event will make a reduction of around 2.05 – 3.15 ML/d, which is well within the observed trend.

The lag effect of demand trend did not show any conclusive results during modelling worth mentioning, but visual inspection of the demand trends and rainfall events show distinct reduction in demand in the period of 24 to 48 hours after the rainfall event and in many instances, the reduction in demand is as high as 4 ML/d.

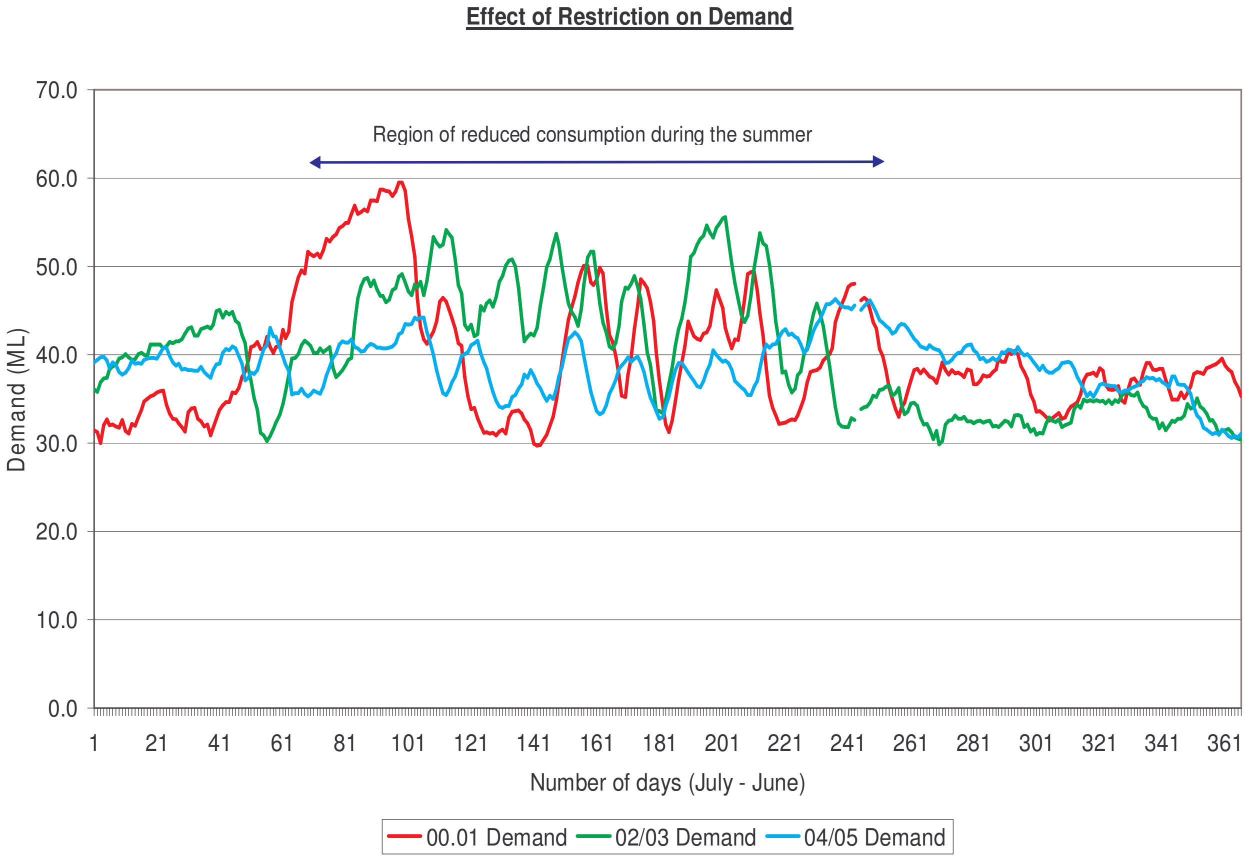
7.1.3 Previous Day and Average Demands

Four sets of demand variables were used as described previously. The best variable coefficient results were obtained when Moving Average Demand (MAD) was used in models. However, best overall results were predictive models 12 and 13 which utilised the 4 day weighted average demand (4dWAD). Although some of the better results were obtained when variables relating to demand were utilised, it significantly reduced the impact of other variables in the model. This is highly undesirable, as important and hence significant trends and patterns could be lost due to over-bearing or imposing demand variables.

7.1.4 Restrictions

Trend observations show that restrictions have been quite effective as means of reducing consumption demand. The figure 7.1 below promptly justifies that even during the usual peak consumption demand summer period, restriction are useful in reducing the demand quite significantly.

Figure 7.1: Actual Demand with and without Restriction



7.2 The Need for Production Optimisation

The growing need to optimise production for TCC emanates from the fact that Mt. Kynoch WTP has the second highest pumping cost in Australia to get water to its treatment plant. Hence, any success in reducing the energy bill of the council would be more than welcome. The current pumping scheduling is designed in an effort to reduce and minimise peak pumping from the two larger lakes, Perseverance and Cressbrook. In 2003/04 alone the cost of peak pumping for the council was $84,307 despite water restrictions in place for most of the year. When this is compared to the peak pumping cost in year 2001/02 of $215,000 with minimal restrictions applicable at the time, the cost becomes telling. The difference in cost of pumping in peak hours and off-peak hours as provided in table 7.1 and provides enough incentive to further reduce peak pumping to an absolute minimum.

Table 7.1: Cost of Peak and Off-Peak Pumping for Mt. Kynoch WTP (2004/05)

Pump	Flow	Tariff	Cost ($)	
Cressbrook	550 L/s (1980 kL/hr)	Off-Peak	195.80/hr	96.45/ML
		Peak	515.75/hr	254.20/ML
Perseverance	420 L/s (1510 kL/hr)	Off-Peak	94.00/hr	60.10/ML
		Peak	247.00/hr	164.05/ML
Cooby				
1 Pump	90 L/s (324 kL/hr)	Normal	41.15.hr	$127.00/ML
2 Pumps	160 L/s (576 kL/hr)	Normal	82.30/hr	142.90/ML
3 Pumps	220 L/s (792 kL/hr)	Normal	123.45/hr	155.90/ML
Booster	315 L/s (1125 kL/hr)	Normal	175.60/hr	156.10/ML

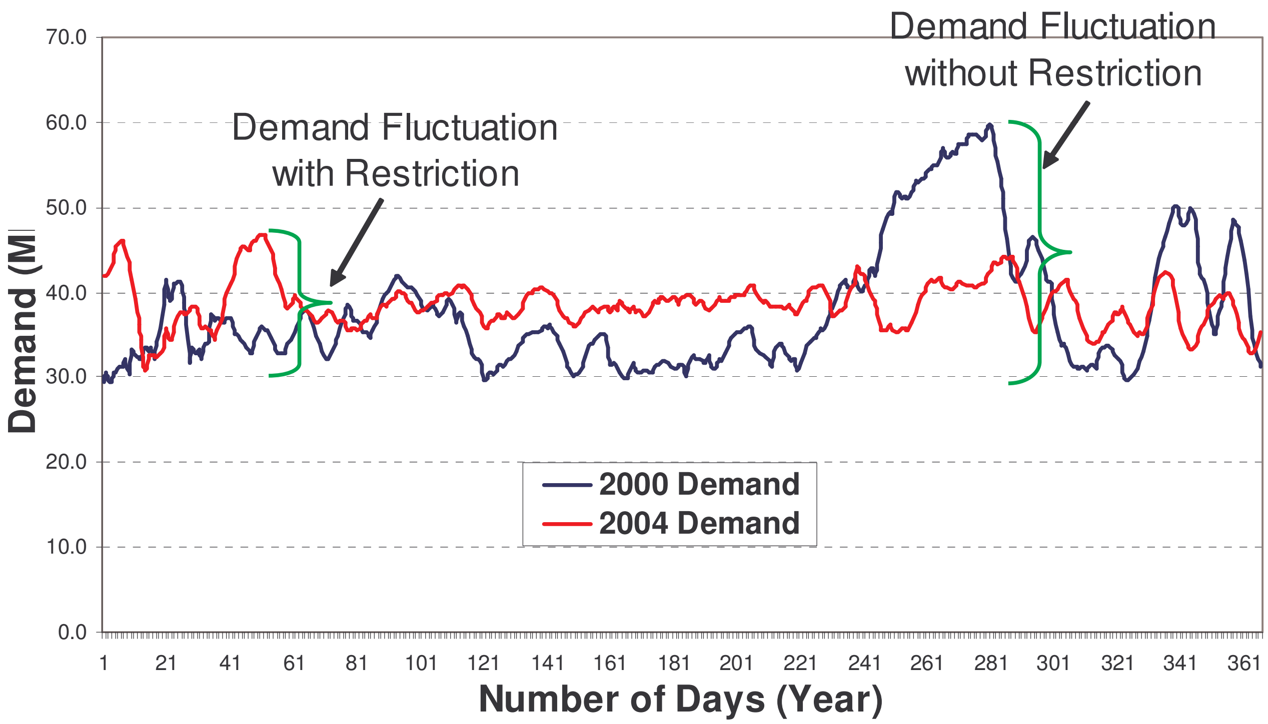
Source: Toowoomba City Council

A forecasting model similar to Model 13 can be used to effectively schedule the pumping regime in a fashion so as to minimise any peak pumping. At least in theory, with a constant carryover volume for necessary services for any 24 hour period, the sum of model 13 errors for year 2004 is -99.50ML/365days. This basically means that according to the forecasted model we would produce more water than what the actual demand warrants, but without going into the more expensive peak tariff pumping.

Since pumping is carried out in two phases, one from lakes to primary water storages and another from the WTP to the distribution reservoirs for the supply network, the production and the pumping have to be synchronised in a strategic manner so that the city continuously has ample supply. This inevitably means that optimisation between the pumping costs, pumping capacities, primary and distribution reservoir storage and production capacity of the plant itself. It should also take into consideration the production response time in case of emergencies. Hence a well designed and accurate forecasting model should enable an equally comprehensive and accurate pumping scheduling which would in return enable the Council to save on its energy bill.

The imposition of restriction in Toowoomba and the continuation of the restriction even in better times will certainly aid in improving the accuracy of the forecasted demand. Imposed restrictions also tend to keep peoples water using habit in check and promote positive water saving mentality and culture in community. Engineering people's water use habit is as important as any other conservation technique, because this will be reflected in future water demand and consumption. Figure 7.2 below reveals the uniformity of the demand trend with imposition of restriction and also shows the erratic nature of demand and hence lower forecasting accuracy for the period without any restriction applied.

Figure 7.2: Demand Fluctuations with and without Restrictions



However, it must be noted that energy bill minimisation and strategic pumping scheduling, as well as production optimisation is more complex function and exercise than the simplification with which it has been portrayed here for the purposes of this dissertation. It is intended on the authors part to impart the importance of accurate forecasting system in the overall operation of the WTP and further elaboration will delve the dissertation into another specialised area, which is beyond the scope of this exercise.

7.3 The Need for Stringent Demand Management

Waterwise, a water conservation arm of TCC is already engaged in awareness and education programs on the delicate position of Toowoomba's freshwater resources. It has facilitated numerous water saving measures including incentives on many fronts as well. However, it has to be stressed the importance of the extra yard in ensuring more water saving practises are introduced and implementation carried through until substantial in-roads are made and sustained. Compulsory legislation can also be passed in quite a number of areas to enhance a change in water use behaviour. These could include some of the following:

- Compulsory reduced water using and water saving devices at all resident dwellings, including lawn sprinkling, reduced volume cisterns, and pressure reduced shower heads. Recent figures from Waterwise indicate the lack of interest in residents claiming rebate on many of the incentives. Many older pre-1985 dwellings still operate with single flush 9 or 12 litre cisterns instead of the water saving newer dual-flush 3-6 litre systems.
- Introduction of compulsory water tanks for all residential dwellings and not just the new establishments as is the current practise. The lawn sprinklers should be connected to the mains as well as the tanks for obvious reasons. Rainwater tanks would also reduce flash flooding and related repercussions due to increased impervious layers as result of recent boom in residential development. Harnessing rainwater will mean that some of the water will be returned to replenish the underground aquifer which is also a vital source of supplement to Toowoomba's freshwater resources.
- Review of the recycling and reuse opportunities for industrial sector. Most food processing plants use a high volume of water in relation to a unit of goods produced and ample opportunities exists if programs are facilitated in this regard.
- Pressure management and leak detection of the supply and distribution systems could lead to potential savings in previously lost water.
- Toowoomba City Council is already looking to recycle wastewater to supplement its water demands. This should be pursued with great intensity, and as advanced technology becomes available, this form of recycling will become the norm in the future. In regards to TCC, it would be ideal to treat and recycle wastewater, as viable options available at the moment are severely limited, and many downright impossible to pursue given the practical and economic reasons.

7.4 Recommendations

The following recommendations have been derived from this study:

1. The apparent benefits of an accurate demand forecasting system should go a long way formalising the demand production criteria of Mt. Kynoch WTP. The system should separate the fixed demand from the fluctuating residential demand more readily explained by the variables investigated in this study. A proposed model 13 would be used in the following manner for demand forecasting on the selected date of 28th December 2004 with given data:

Actual Demand *(ML)*	**=**	**30.20**
Temperature	=	23.50
Rainfall *(mm)*	=	5.80
Raindays	=	1
4dWAD *(ML)*	=	31.35
Restriction Level	=	3

$$\textbf{Forecasted Demand} = \textbf{3.58} + \textbf{0.17*Temperature} - \textbf{0.1*Rainfall} - \textbf{2.41*Raindays} + \textbf{0.85*4dWAD} - \textbf{0.33*Restrictions} \qquad \textbf{(7.1)}$$

Where:

$\boldsymbol{B_0}$ = 3.58 = Y-Intercept from regression.

Variable coefficients as given in the above equation

Therefore,

Forecasted demand	**= 30.24** ***(ML)***
Regression Error Tolerance	= ± 3.35 *(ML)*
Calculated Error	= - 0.04 *(Over-estimated)*

It follows that generally the forecasted demand can be quite accurate as in the above selected case. Only in extreme conditions does the model gives significant errors.

More, general and accurate application can be derived from the equation given below, which can be used with any predictive model.

Forecasted Demand = Base Demand + Fluctuating Demand **(7.2)**

Where:

Base Demand	= Fixed demand i.e. industrial, commercial, essential service allowances + Y-intercept from the regression model.
Fluctuating Demand	= primarily residential demand regression model as a function of the investigated variables.

Fluctuating demand for Toowoomba according to the modelling is best explained by maximum air temperature, rain-days, rainfall-weights, restrictions and moving average demand. However, it must be noted that:

i. Accurate forecasting of future demands is highly dependent on the duration and quality of database at hand. This study only utilised 4 years of demand data due to inconsistencies observed in actual demand data recorded prior to year 2000, rendering a large chunk of data unusable.

ii. Acquisition and implementation of an up-marketed and hence more accurate forecasting system in place with forecasting capabilities of a magnitude of short-term durations including 24 hour ahead to a week in advance. This will allow for at least a week ahead of pumping scheduling and accurate production purposes.

2. It is recommended that a minimum level of restriction is maintained at all times for both reduction of pumping and production costs and enhance a sense of responsibility and concern for the municipal potable water resources. It works out with certain minimum restrictions levels, the degree of activities that can attained is still the same, with far less use of the city's water supply.

7.5 Limitations of Study

The primary limitation of the accuracy of the forecasting model was the unavailability of reliable and accurate demand data for a larger duration. The fact that several years' data prior to year 2000 had to be omitted from the study left only 4 years of data to determine the variable strengths and trends. Apart from this, future recordings of demand data should be synchronized with timing of recording of climatic variables used in determining the forecasted demand. As it stands, most of the meteorological readings are taken at around 0900 HRS, and actual demand and pumping data should also be recorded at that particular time.

The second issue was associated with the methodology utilised as regressive models tends to average and smooth out the peaks and troughs, and at times seriously underestimating or overestimating at these instances. Literature on the demand forecasting has found that although regression models offer a reliable forecasting tool, ANNs generally tend to give better results with less stringent data requirements. However, the downside is that the expertise and time requirements of ANNs invariably rendered its application for this study as impractical.

CHAPTER 8

CONCLUSION

8.0 CONCLUSION

> ***"And it failed during the dry years the people forgot about the rich years and during the wet years they lost all memory of the dry years. It was always that way."***
>
> ***- John Steinbeck. East of Eden***

The growing population, urban development, and hydrological changes due to climate changes has left TCC facing serious long-term challenges in its quest to provide continuous portable water to its citizens. While not triggering the panic stage yet, it has prompted TCC to address the consequences of drought conditions and curb demands through various Waterwise programs and more effectively through imposed water restrictions. Hence, for effective production optimizations and water demand management measures to be implemented and sustained, a short-term 24 hour demand forecasting model was developed for TCC.

The model took into account several variables including most climatic factors, and investigated several average demand variables for the predictability of 24 hour ahead demand. Lastly, the effect of restriction was investigated on daily water demand. Most climate variables showed reasonable strength and trends to the daily water demand of Toowoomba. Maximum temperature quite effectively catered for peak demand, and temperature difference between the maximum and the minimum provided excellent general application, taking into account effect of both the higher and the lower temperatures on the demand.

Rainfall also showed strong trends in reduction of demand within the first 24 to 48 hour period, in some cases the demand falling by 7-10 ML in the first 24 hour. There exists a well defined lag phase in the consumption trend and more accurate future models should take this into account. However, it was duly noticed that rain-days provided closer relationship trend to the demand patterns and usually proved to be the stronger of the two rainfall variables used. More so, an extra variable derived from the study in an attempt to combine both the rainfall amount and rain-days provided the best trend relation and the use of this variable should be pursued in the future.

The four demand variations used provided strong trend relation to the actual demand, especially the moving average demand and the 4-day weighted average demand. However, since the demand variations are such a strong variable in regards to actual demand, it can obscure the important effect and trend of other variables, especially in instances of extreme demand, where it tends to average out the predictive strength, and under or over-estimate the forecasted demand.

Of the conservatory tools, the imposition of restriction levels is most effective in reducing the demand. The lack of reasonable duration of restriction data did not provide any significant effect on the models, but visual inspection of actual demand trends clearly indicate a significant reduction of demand over the period of as restriction subsequently increased.

A general model which separates the demand into fixed and fluctuating has been proposed which takes into account variable including maximum temperature, rainfall weightings, moving average demand, and imposed restrictions. Given the nature of the model variables, these can be applied to durations of 24 hour to a week ahead with reasonable accuracy. However, the use of regression technique does tend to average out the forecasted demand, especially at instances of higher demands.

Lastly, TCC should vigorously continue with its water conservation programs to the point of sustained reduction in consumption demand as well to make a permanent change in the behaviour of water consumption, with increased awareness among its citizens. By engaging in programs such as wastewater recycling to augment its freshwater supplies in its Water Futures program, Toowoomba City Council is well positioned in the heart of Darling Downs region to become a powerful player in municipal water supply.

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APPENDIX A

FINAL YEAR PROJECT SPECIFICATION

Appendix A: Final Year Project Specification

ENG 4111/2 Research Project
Project Specification as at 4th March 2005

For: Ravindra S. Pillay

Topic: Short-Term Water Demand Forecasting for Production Optimization

Supervisor: Dr. David Thorpe

Ass. Supervisor: Mr. Gareth Finlay, Mt. Kynoch WTP, TCC

Enrolment: ENG 4111 – S1, ONC, 2005

Sponsorship: Water and Waste Operations, Toowoomba City Council.

Project Aim: To develop an acceptable demand prediction model for short-term pumping strategies and demand management for Toowoomba City Council.

Programme:

1. Research background information and literature relating to demand forecasting and demand management.
2. Review current operating procedures and identify measures taken for production optimisation and demand management.
3. Analyse water consumption trends for City of Toowoomba.
4. Data acquisition and quality analysis of appropriate duration of data.
5. Develop an appropriate demand prediction model.
6. Prepare and submit the required project dissertation as per Project Reference Guide, 2005.

As time permits:

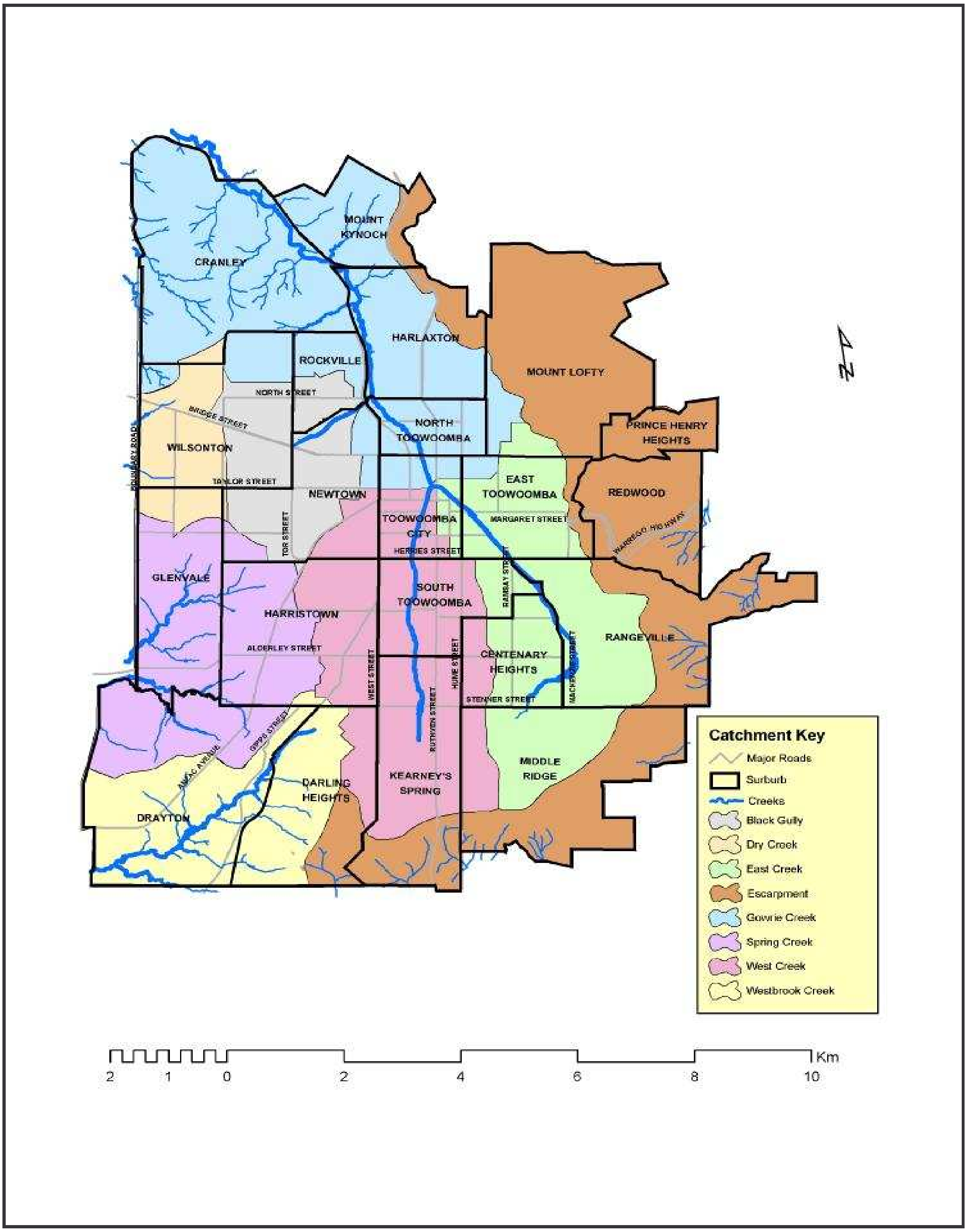
7. Assess the reliability of model and confidence levels through comparison to actual demand.
8. Compare model results with other similar demand forecasting models.

______________	______________	______________
Dr. David Thorpe	Mr. Gareth Finlay	Ravindra Pillay

APPENDIX B

TOOWOOMBA CATCHMENT AREA

<u>Appendix B: Toowoomba Catchment Area</u>

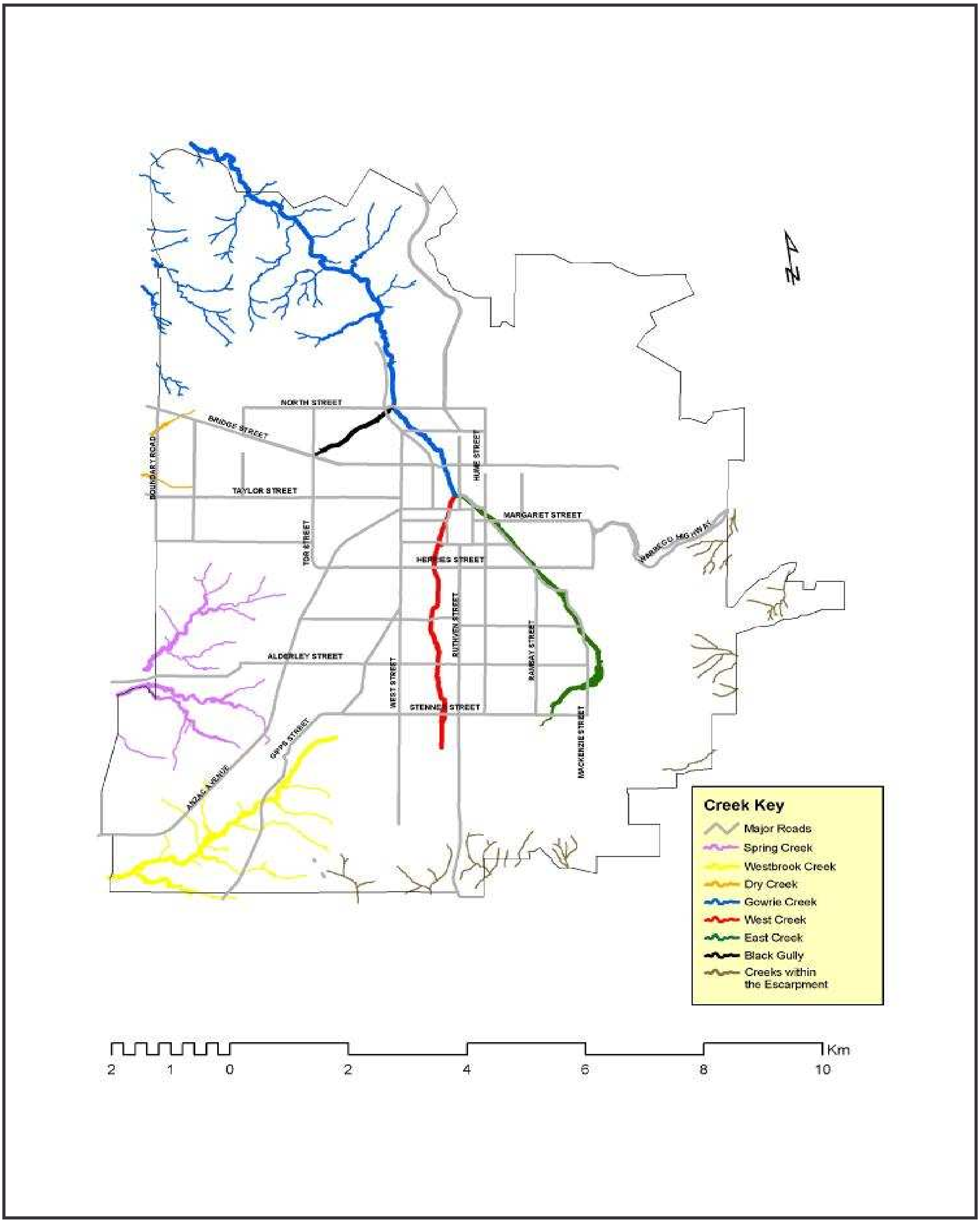


Source: Toowoomba City Council

APPENDIX C

WATERWAYS OF TOOWOOMBA

Appendix C: Waterways of Toowoomba

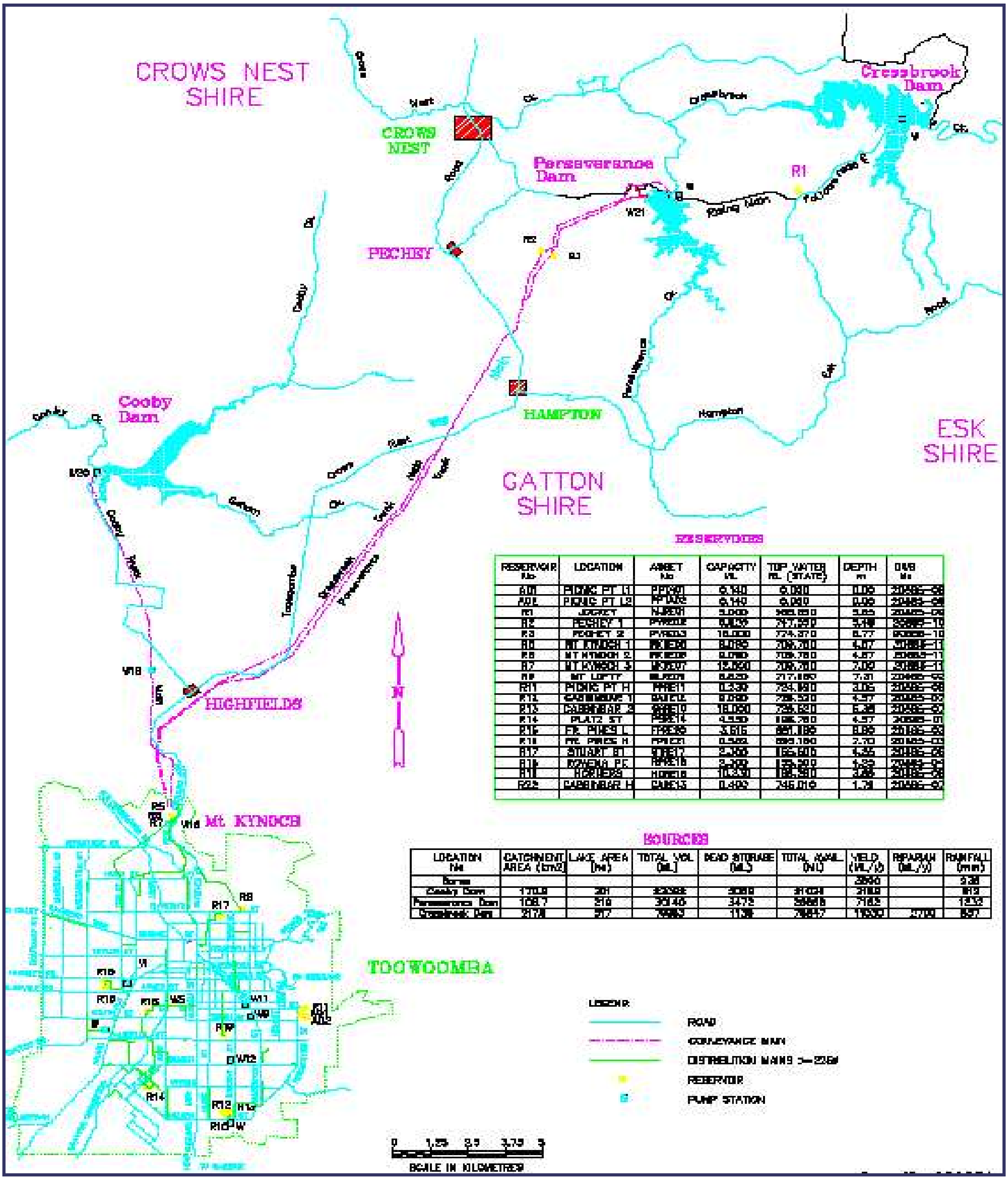


Source: Toowoomba City Council

APPENDIX D

WATER SUPPLY SOURCES, RESERVOIRS AND MAJOR TRUNK MAINS

Appendix D: Water Supply Sources, Reservoirs and Major Trunk Mains



RESERVOIRS

RESERVOIR No	LOCATION	ASSET No	CAPACITY ML	TOP WATER RL (STATE)	DEPTH m	DWG No
A01	PICNIC PT L1	PPTA01	6.140	6.080	0.06	[illegible]
A02	PICNIC PT L2	PPTA02	6.140	6.080	0.06	[illegible]
R1	JOCKEY	[illegible]	5.000	[illegible]	5.65	[illegible]
R2	PECHEY 1	PVRE02	[illegible]	747.250	[illegible]	[illegible]
R3	PECHEY 2	PVRE03	10.000	774.370	8.77	[illegible]
R5	MT KYNOCH 1	[illegible]	[illegible]	706.780	4.67	[illegible]
R6	MT KYNOCH 2	[illegible]	[illegible]	706.780	4.67	[illegible]
R7	MT KYNOCH 3	[illegible]	15.650	706.780	7.09	[illegible]
R8	MT LOFTY	[illegible]	6.620	717.650	7.31	[illegible]
R11	PICNIC PT H	PPRE11	0.230	724.890	3.06	[illegible]
R12	CABBINBAR 1	[illegible]	[illegible]	726.520	4.57	[illegible]
R13	CABBINBAR 2	[illegible]	10.050	726.520	6.38	[illegible]
R14	PLATZ ST	[illegible]	4.550	[illegible]	4.57	[illegible]
R15	FR PINES L	[illegible]	3.616	[illegible]	8.85	[illegible]
R16	FR PINES H	[illegible]	0.562	[illegible]	7.70	[illegible]
R17	STUART ST	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
R18	ROWENA PC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
R19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
R22	CABBINBAR H	[illegible]	0.402	746.016	1.79	[illegible]

SOURCES

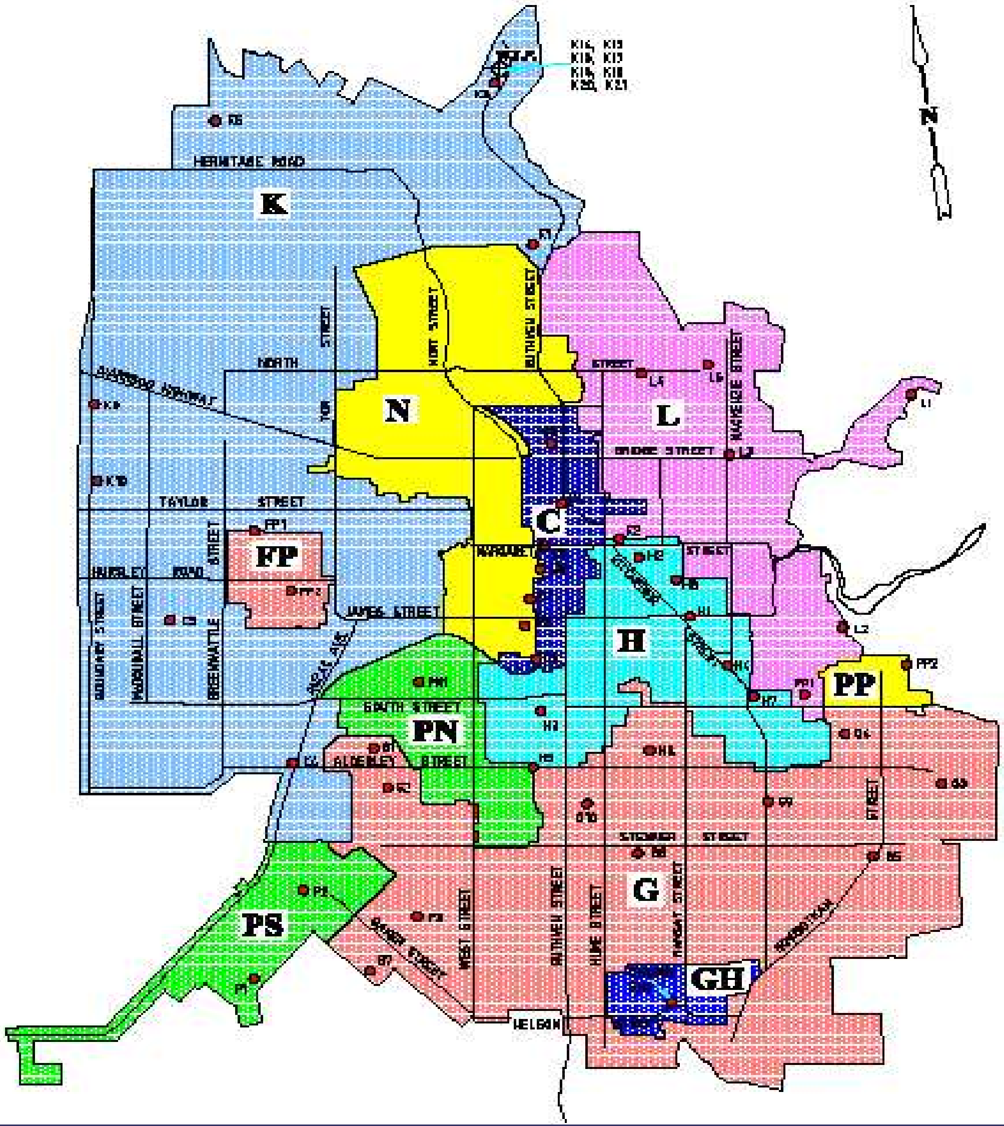
LOCATION No	CATCHMENT AREA (km2)	LAKE AREA (ha)	TOTAL VOL (ML)	DEAD STORAGE (ML)	TOTAL AVAIL (ML)	YIELD (ML/y)	RIPARIAN (ML/y)	RAINFALL (mm)
Bores						[illegible]		[illegible]
Cooby Dam	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Perseverance Dam	108.7	210	30140	3472	[illegible]	7162		1232
Cressbrook Dam	[illegible]	517	[illegible]	[illegible]	[illegible]	[illegible]	2700	[illegible]

Source: Toowoomba City Council

APPENDIX E

PRESSURE ZONES OF TOOWOOMBA SUPPLY SYSTEM GRID

<u>Appendix E: Pressure Zones of Toowoomba Supply System Grid</u>



Zones	
Symbol	Location
C	CITY ZONE
FP	FRENEAU PINES ZONE
G	GABBINBAR ZONE
GH	GABBINBAR HIGH ZONE
H	HORNERS ZONE
K	KYNOCH ZONE
L	LOFTT ZONE
N	NORTHERN ZONE
PP	PICNIC POINT ZONE
PN	PLATZ ZONE NORTH
PS	PLATZ ZONE SOUTH

Symbol	Location	Type
C1	City Library	GT
C2	Wilsonton Soccer	CT
C3	Stephen Street	B
C4	McCrum Lane	B
C5	Mylne Bay	B
FP1	George Orford Park	CT
FP2	Freneau Pines Tower	R
G1	Harristown Park	CT
G2	Smithfield Park	GT
G3	SPS 37	CT
G4	Rangeville Park	GT
G5	SPS 37	CT
G6	Middle Ridge Park	GT
G7	SPS 10 Hendley Street	GT
G8	Ballin Drive	B
G10	Neil E Robinson Park	B
GH1	Gabbinbar Elevated	R
GH2	Gabbinbar No.1	R
GH3	Gabbinbar No.2	R
H1	Information Centre	GT
H2	East Creek Park	CT
H3	City Golf Club	GT
H4	Lake Annand	CT
H5	Alderley Street	B
H6	Creek Street	B
H7	Eastern Valley	B
H8	Horners	R
K1	Blue Mountain Reserve	GT
K2	Queens Park	B
K3	Fechey Street (Northern Zone)	GT
K4	SPS 8	GT
K5	SPS 33	GT
K6	Bedford Street Tip	CT
K7	Boggs Street (Northern Zone)	B
K8	Kynoch	R
K9	DP5 Bridge Street SPS 8	Bulk
K10	DP8 Taylor Street SPS 10	Bulk
K11	DP10 Downs Junction Offtake	Bulk
K12	DP9 Westbrook	Bulk
K13	DP7/8/11 Chamberlain Road	Bulk
K14	Lower Gallery No.1	B
K15	Lower Gallery No.2	B
K16	Lower Gallery No.3	B
K17	Lower Gallery No.4	B
K18	Lower Gallery No.5	B
K19	Lower Gallery No.6	B
K20	Lower Gallery No.7	B
K21	Lower Gallery No.8	B
L1	SPS 27	GT
L2	SPS 36	CT
L4	Stuart Street	R
L5	Lofty	R
P1	SPS 6	GT
P2	Garnett Peak Park	GT
P3	Platz	R
PN1	Rowena	R
PP1	Parsons Street Park	GT
PP2	Picnic Point	R

Towers	
Symbol	Location
C3	Stephen Street
C4	McCrum Lane
C5	Mylne Bay
G9	Ballin Drive
G10	Neil E Robinson Park
H5	Alderley Street
H6	Creek Street
H7	Eastern Valley
K2	Queens Park
K7	Boggs Street (Northern Zone)

Bulk Water	
Symbol	Location
K9	DP5 Bridge Street SPS 8
K10	DP8 Taylor Street SPS 10
K11	DP10 Downs Junction Offtake
K12	DP9 Westbrook
K13	DP7/8/11 Chamberlain Road

Consumer Type	
Symbol	Location
C1	City Library
C2	Wilsonton Soccer
FP1	George Orford Park
G1	Harristown Park
G2	Smithfield Park
G3	SPS 65
G4	Rangeville Park
G5	SPS 37
G6	Middle Ridge Park
G7	SPS 15 Hendley Street
H1	Information Centre
H2	East Creek Park
H3	City Golf Club
H4	Lake Annand
K1	Blue Mountain Reserve
K3	Fechey Street (Northern zone)
K4	SPS 5
K5	SPS 83
K6	Bedford Street Tip
L1	SPS 27
L3	SPS 36
P1	SPS 6
P2	Garnett peak Park
PP1	Parsons Street Park

Water Treatment Plant	
Symbol	Location
K14	Lower Gallery No.1
K15	Lower Gallery No.2
K16	Lower Gallery No.3
K17	Lower Gallery No.4
K18	Lower Gallery No.5
K19	Lower Gallery No.6
K20	Lower Gallery No.7
K21	Lower Gallery No.8

Reservoirs	
Symbol	Location
FP2	Freneau Pines Tower
GH1	Gabbinbar Elevated
GH2	Gabbinbar No.1
GH3	Gabbinbar No.2
H8	Horners
K8	Kynoch
L4	Stuart Street
L5	Lofty
P3	Platz
PN1	Rowena
PP2	Picnic Point

APPENDIX F

PRELIMINARY TRIAL MODEL SELECTION MATRIX

<u>Appendix F: Preliminary Trial Model Selection Matrix</u>

Variable	Temp.*	Rainfall	Rain days	Dt-1*	MAD*	4dWAD*	7dWAD*	Restrict*	Evap.*	Temp.* Dev.	Temp.* Diff.	R.W.*
TM*-1	●											
TM-2		●										
TM-3			●									
TM-4				●								
TM-5					●							
TM-6						●						
TM-7							●					
TM-8								●				
TM-9									●			
TM-10										●		
TM-11											●	
TM-12												●
TM-13	●	●										
TM-14	●	●	●									
TM-15	●	●	●	●								
TM-16	●	●	●		●							
TM-17	●	●	●			●						
TM-18	●	●	●				●					
TM-19	●	●	●					●				
TM-20	●	●	●						●			
TM-21		●	●	●								
TM-22	●	●	●		●							
TM-23		●	●			●						
TM-24		●	●				●					

Variable	Temp.*	Rainfall	Rain days	Dt-1*	MAD*	4dWAD*	7dWAD*	Restrict*	Evap.*	Temp.* Dev.	Temp.* Diff.	R.W.*
TM-25	●	●	●					●				
TM-26	●	●	●	●								
TM-27		●	●							●		
TM-28	●	●	●									
TM-29	●	●	●			●		●				
TM-30		●	●		●					●		
TM-31		●	●			●				●		
TM-32		●	●				●			●		
TM-33		●	●					●		●		
TM-34		●	●						●	●		
TM-35		●	●	●							●	
TM-36		●	●		●						●	
TM-37		●	●			●					●	
TM-38	●	●	●				●					
TM-39		●	●					●			●	
TM-40		●	●						●		●	
TM-41	●	●										●
TM-42	●	●		●								●
TM-43	●	●			●							●
TM-44	●	●				●						●
TM-45	●	●					●					●
TM-46	●	●						●				●
TM-47	●	●							●			●
TM-48	●	●	●				●	●				
TM-49	●	●	●					●				
TM-50	●	●						●	●			

Variable	Temp.*	Rainfall	Rain days	Dt-1*	MAD*	4dWAD*	7dWAD*	Restrict*	Evap.*	Temp.* Dev.	Temp.* Diff.	R.W.*
TM-51	●	●				●		●	●			
TM-52					●					●		
TM-53					●						●	
TM-54					●							●
TM-55			●		●			●		●		
TM-56			●		●			●			●	
TM-57		●						●	●	●		
TM-58	●				●			●				●
TM-59					●			●		●		●
TM-60					●			●			●	●
TM-61	●	●	●		●			●		●	●	●

Keys: *

TM	- Preliminary Trial Model
Temp.	- Maximum Daily Air Temperature
Dt-1	- Previous day demand
MAD	- Moving Average Demand
4dWAD	- 4 Day Weighted Average Demand
7dWAD	- 7 day Weighted Average Demand
Restrict.	- Applicable Water Restrictions (Refer Table X and Appendix 2 for further information)
Evap.	- Daily Evaporation (mm)
Temp. Dev.	- Maximum Temperature Deviation from Mean.
Temp. Diff.	- Temperature difference between the maximum and Minimum air temperatures
R.W.	- Rainfall Weightings (Refer table X for further information)

APPENDIX G

MODEL RESULTS

Appendix G: Model Results

Statistical Measure	R^2	Adjusted R^2	Standard Error	F Statistic	Durban Watson Statistic	Critical F Statistic
MODEL – 1	0.2792	0.2782	5.83	282	0.964	3.002
MODEL – 2	0.2145	0.2134	5.84	199	0.836	2.609
MODEL – 3	0.7402	0.7397	3.49	1384	1.932	2.611
MODEL – 4	0.5788	0.5779	4.46	667	2.222	2.611
MODEL – 5	0.7431	0.7426	3.47	1405	1.475	2.611
MODEL – 6	0.6348	0.6340	4.14	844	1.240	2.611
MODEL – 7	0.3485	0.3470	5.54	259	0.792	2.611
MODEL – 8	0.7470	0.7463	3.45	1074	1.989	2.378
MODEL – 9	0.7470	0.7460	3.46	859	1.987	2.220
MODEL – 10	0.6080	0.6070	4.30	565	2.375	2.378
MODEL – 11	0.3240	0.3230	6.00	349	0.510	2.609
MODEL – 12	0.7610	0.7602	3.35	1159	1.680	2.378
MODEL – 13	0.7618	0.7611	3.35	930	1.662	2.220
MODEL – 14	0.6646	0.6637	3.97	721	1.404	2.378
MODEL – 15	0.6665	0.6654	3.97	581	1.382	2.220
MODEL – 16	0.3942	0.3925	5.34	236	0.844	2.378
MODEL – 17	0.7280	0.7277	3.58	1951	1.983	3.002
MODEL – 18	0.7274	0.7270	3.58	1945	1.967	3.002
MODEL – 19	0.7386	0.7383	3.51	2080	2.048	3.002
MODEL – 20	0.7366	0.7359	3.53	1017	1.942	2.378
MODEL – 21	0.7393	0.7386	3.51	1032	1.993	2.378
MODEL – 22	0.7437	0.7430	3.48	1056	2.068	2.378
MODEL – 23	0.7395	0.7388	3.51	1033	2.064	2.378
MODEL – 24	0.7390	0.7383	3.51	1030	2.053	2.378
MODEL – 25	0.7470	0.7458	3.46	613	2.053	2.016

NB: Selected Models in color

APPENDIX H

RESULTS OF MODEL PARAMETERS

Appendix H: Result of Model Parameters

Parameters	Base Demand	Standard Error (±)	Temp.	Rain	Rain days	Dt-1	MAD	4dWAD	7dWAD	Restrict	Temp. Dev.	Temp. Diff.	R.W.
MODEL – 1	25.78	5.83	0.62	-0.22									
MODEL – 2	36.29	5.84	0.22	0.12	-6.42								
MODEL – 3	-1.93	3.49	0.11	-0.10			0.99						
MODEL – 4	9.04	4.46	0.31	-0.16		0.60							
MODEL – 5	0.90	3.47	0.17	-0.17				0.89					
MODEL – 6	1.71	4.14	0.25	-0.23					0.82				
MODEL – 7	30.00	5.54	0.62	-0.23						-2.83			
MODEL – 8	-0.48	3.45	0.11	-0.06	-1.50		0.96						
MODEL – 9	-0.37	3.46	0.11	-0.07	-1.50		0.96			-0.04			
MODEL – 10	11.03	4.30	0.29	-0.08	-3.09	0.57							
MODEL – 11	25.91	6.00	0.61	-0.08	-4.69								
MODEL – 12	2.72	3.35	0.16	-0.10	-2.42			0.86					
MODEL – 13	3.58	3.35	0.17	-0.10	-2.41			0.85		-0.33			
MODEL – 14	3.82	3.97	0.23	-0.15	-3.10				0.79				
MODEL – 15	5.27	3.97	0.24	-0.15	-3.07				0.77	-0.52			
MODEL – 16	31.44	5.34	0.58	-0.12	-3.83					-2.65			
MODEL – 17	-2.81	3.58					1.03				0.28		
MODEL – 18	-2.68	3.58					1.03					0.12	
MODEL – 19	-0.92	3.51					1.03						-1.00
MODEL – 20	-1.92	3.53			-0.09		1.02			0.07	0.17		
MODEL – 21	-0.60	3.51			-1.91		1.02			0.13		0.02	
MODEL – 22	-1.37	3.48	0.11				0.98			0.00			-1.05
MODEL – 23	-1.47	3.51					1.02			0.11	0.14		-0.96
MODEL – 24	-1.42	3.51					1.03			0.13		0.03	-0.96
MODEL – 25	-0.46	3.46	0.11		-1.26		0.97			0.01	0.15	0.11	-0.68

NB: All variable coefficients and equation parameters of selected models shown in color

APPENDIX I

SOFTWARE MODEL OUTPUTS

Appendix I.1: Output for Model 3

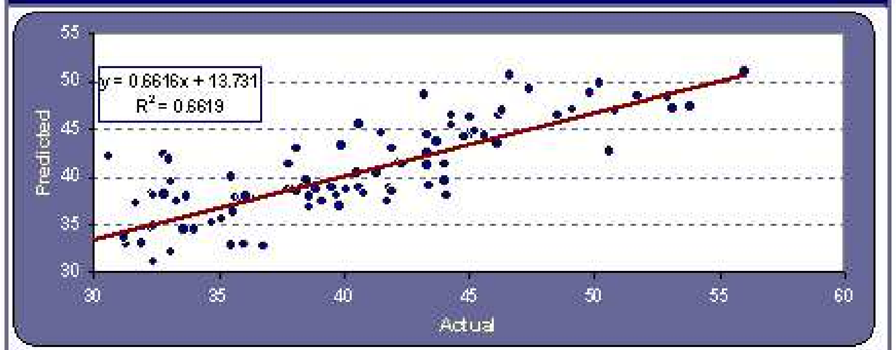
Equation Parameters		
R Square	0.7402	74.02% of the change in Demand can be explained by the change in the 3 Independent Variables
Adjusted R Square	0.7357	Adjusted for Sample Size bias
Standard Error	3.4993	to +/- on result of Regression Equation
F-Statistic	1384.0443	Therefore analysis IS Significant

1.93170	Durbin-Watson Statistic	Critical D-W Values: Lower (Dl)=1.61; Upper (Du)=1.74
	Therefore No Autocorrelation detected at 95% Confidence	
2.61100	Critical F-Statistic at 95% Confidence	(Significance holds to 100.0% Level of Confidence)

Multiple Regression Equation			Independent Analysis			Auto Correlation	Tests for Multicolinearity between Independent Variables	Independent R-Square Matrix			
	Coefficients	Standard Error	R Squared	Gradient	Intercept	Dl=1.65 Du=1.69 DW Score	Adjusted R-Squared against other Indep	Temp	Rainfall	MAD	
Intercept	-1.927	0.689									
Temp	0.107	0.020	22.63%	0.63	25.00	0.58	44.97%	100%	0%	29%	Temp
Rainfall	-0.103	0.013	6.00%	-0.23	40.19	0.49	6.64%	0%	100%	3%	Rainfall
MAD	0.991	0.020	72.50%	1.06	-2.54	0.09	45.59%	29%	3%	100%	MAD

Demand = 0.11*Temp + -0.10*Rainfall + 0.99*MAD + -1.93 (+/- 3.50)

Actual versus Predicted Demand



Step 2 - Forecasting

Trend R-Squared Matrix

Independent Variable	3rd Ord Polynomial	2nd Ord Polynomial	Exponential	Linear	Choose Method
Temp	4%	4%	#####	11%	Linear
Rainfall	2%	1%	#####	2%	Linear
MAD	0%	0%	#####	8%	Linear

Number of Periods to Forecast: 10

Appendix I.2: Output for Model 5

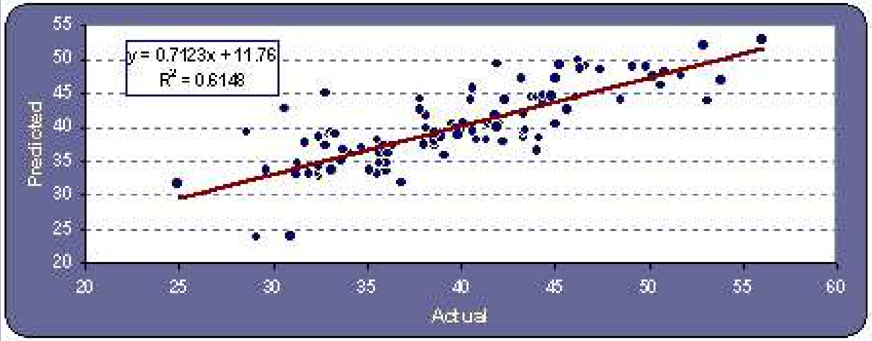
Equation Parameters		
R Square	0.7431	74.31% of the change in Demand can be explained by the change in the 3 Independent Variables
Adjusted R Square	0.7426	Adjusted for Sample Size bias
Standard Error	3.4798	to +/- on result of Regression Equation
F - Statistic	1405.0668	Therefore analysis IS Significant

1.47452	Durbin-Watson Statistic	Critical D-W Values: Lower (Dl)=1.61; Upper (Du)=1.74
	Therefore Positive Autocorrelation detected at 95% Confidence	
2.61100	Critical F-Statistic at 95% Confidence	(Significance holds to 100.0% Level of Confidence)

Multiple Regression Equation			Independent Analysis			Auto Correlation	Tests for Multicolinearity between Independent Variables				
	Coefficients	Standard Error	R Squared	Gradient	Intercept	Dl=1.65 Du=1.69 DW Stat	Adjusted R-Squared against other Indep	Independent R-Square Matrix			
								Temp	Rainfall	4dWAD	
Intercept	0.900	0.641									
Temp	0.171	0.020	22.63%	0.63	25.00	0.58	32.82%	100%	0%	20%	Temp
Rainfall	-0.165	0.013	6.00%	-0.23	40.19	0.45	4.81%	0%	100%	1%	Rainfall
4dWAD	0.885	0.017	70.07%	0.97	1.17	0.16	30.36%	20%	1%	100%	4dWAD

Demand = 0.17*Temp + -0.17*Rainfall + 0.89*4dWAD + 0.90 (+/- 3.48)

Actual versus Predicted Demand



Step 2 - Forecasting

Trend R-Squared Matrix

Independent Variable	3rd Ord Polynomial	2nd Ord Polynomial	Exponential	Linear	Choose Method
Temp	4%	4%	#####	11%	Linear
Rainfall	2%	1%	#####	2%	Linear
4dWAD	0%	0%	#####	3%	Linear

Number of Periods to Forecast: 10

Appendix I.3: Output for Model 8

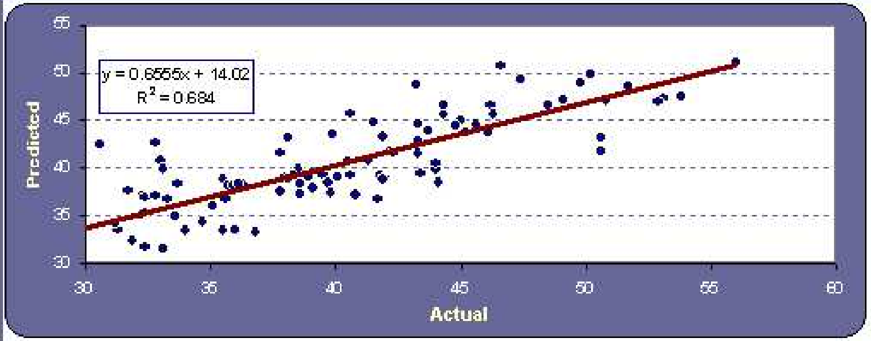
Equation Parameters		
R Square	0.7470	74.70% of the change in Demand can be explained by the change in the 4 Independent Variables
Adjusted R Square	0.7463	Adjusted for Sample Size bias
Standard Error	3.4549	to +/- on result of Regression Equation
F - Statistic	1074.5107	Therefore analysis IS Significant

1.98970	Durbin-Watson Statistic	Critical D-W Values: Lower (Dl)=1.59; Upper (Du)=1.76
	Therefore No Autocorrelation detected at 95% Confidence	
2.37802	Critical F-Statistic at 95% Confidence	(Significance holds to 100.0 % Level of Confidence)

Multiple Regression Equation			Independent Analysis			Auto Correlation	Tests for Multicolinearity between Independent Variables					
	Coefficients	Standard Error	R Squared	Gradient	Intercept	Dl=1.65 Du=1.69 DW-Stat	Adjusted R-Squared against other Indep	Independent R-Square Matrix				
Intercept	-0.477	0.719										
Temp	0.106	0.020	22.63 %	0.63	25.00	0.58	44.44 %	100%	0%	2%	25%	Temp
Rainfall	-0.065	0.014	6.00 %	-0.23	40.19	0.49	21.10 %	0%	100%	21%	3%	Rainfall
Raindays	-1.504	0.242	14.20 %	-5.92	41.25	1.36	18.12 %	2%	21%	100%	10%	Raindays
MAD	0.963	0.020	72.50 %	1.06	-2.54	0.09	45.68 %	25%	3%	10%	100%	MAD
								Temp	Rainfall	Raindays	MAD	

Demand = 0.11*Temp + -0.06*Rainfall + -1.50*Raindays + 0.96*MAD + -0.48 (+/- 3.45)

Actual versus Predicted Demand



Step 2 - Forecasting

Trend R-Squared Matrix Independent Variable	3rd Ord Polynomial	2nd Ord Polynomial	Exponential	Linear	Choose Method
Temp	4%	4%	#####	11%	Linear
Rainfall	2%	1%	#####	2%	Linear
Raindays	0%	0%	#####	0%	Linear
MAD	0%	0%	#####	8%	

Number of Periods to Forecast: 10

Appendix I.4: Output for Model 9

Equation Parameters		
R Square	0.7470	74.70% of the change in Demand can be explained by the change in the 5 Independent Variables
Adjusted R Square	0.7461	Adjusted for Sample Size bias
Standard Error	3.4561	to +/- on result of Regression Equation
F - Statistic	859.0627	Therefore analysis IS Significant

1.98653	Durbin-Watson Statistic	Critical D-W Values: Lower (Dl)=1.57; Upper (Du)=1.78	
	Therefore No Autocorrelation detected at 95% Confidence		
2.22023	Critical F-Statistic at 95% Confidence		(Significance holds to 100.0 % Level of Confidence)

Multiple Regression Equation / **Independent Analysis** / **Auto Correlation**

	Coefficients	Standard Error	R Squared	Gradient	Intercept	Dl=1.65 Du=1.69 DW-Stat
Intercept	-0.366	0.857				
Temp	0.107	0.021	22.63 %	0.63	25.00	
Rainfall	-0.065	0.014	6.00 %	-0.23	40.19	
Raindays	-1.505	0.242	14.20 %	-5.92	41.25	
MAD	0.961	0.021	72.50 %	1.06	-2.54	
Restriction	-0.037	0.157	6.89 %	-2.90	44.17	

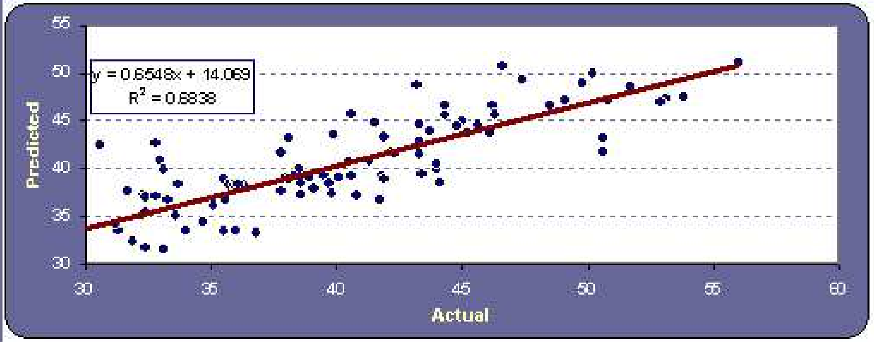
Tests for Multicolinearity between Independent Variables

Independent R-Square Matrix

Adjusted R-Squared against other Indep	Temp	Rainfall	Raindays	MAD	Restriction	
	100%	0%	2%	25%	0%	Temp
	0%	100%	21%	3%	0%	Rainfall
	2%	21%	100%	10%	0%	Raindays
	25%	3%	10%	100%	11%	MAD
	0%	0%	0%	11%	100%	Restriction

Demand = 0.11*Temp + -0.07*Rainfall + -1.50*Raindays + 0.96*MAD + -0.04*Restriction + -0.37 (+/- 3.46)

Actual versus Predicted Demand



Step 2 - Forecasting

Trend R-Squared Matrix / Independent Variable	3rd Ord Polynomial	2nd Ord Polynomial	Exponential	Linear	Choose Method
					Linear
					Linear
					Linear

Number of Periods to Forecast: 10

Appendix I.5: Output for Model 12

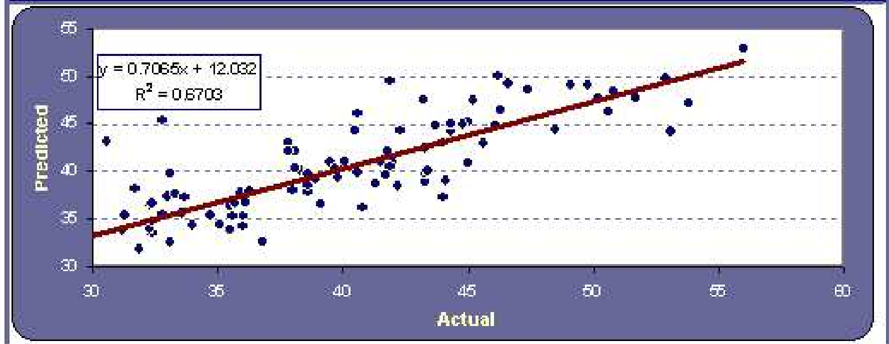
Equation Parameters		
R Square	0.7611	76.11% of the change in Demand can be explained by the change in the 4 Independent Variables
Adjusted R Square	0.7604	Adjusted for Sample Size bias
Standard Error	3.3572	to +/- on result of Regression Equation
F - Statistic	1159.4913	Therefore analysis IS Significant

1.68026	Durbin-Watson Statistic	Critical D-W Values: Lower (Dl)=1.59; Upper (Du)=1.76
	Therefore Positive Autocorrelation maybe present at 95% Confidence	
2.37802	Critical F-Statistic at 95% Confidence	(Significance holds to 100.0 % Level of Confidence)

Multiple Regression Equation			Independent Analysis			Auto Correlation	Tests for Multicolinearity between Independent Variables					
						Dl=1.65 Du=1.69		Independent R-Square Matrix				
	Coefficients	Standard Error	R Squared	Gradient	Intercept	DW-Stat	Adjusted R-Squared against other Indep	Temp	Rainfall	Raindays	4dWAD	
Intercept	2.717	0.643										
Temp	0.159	0.019	22.63%	0.63	25.00	0.58	32.70%	100%	0%	2%	20%	Temp
Rainfall	-0.100	0.014	6.00%	-0.23	40.19	0.49	20.91%	0%	100%	21%	1%	Rainfall
Raindays	-2.421	0.232	14.20%	-5.92	41.25	1.36	17.70%	2%	21%	100%	5%	Raindays
4dWAD	0.859	0.017	70.07%	0.97	1.17	0.16	30.11%	20%	1%	5%	100%	4dWAD

Demand = 0.16*Temp + -0.10*Rainfall + -2.42*Raindays + 0.86*4dWAD + 2.72 (+/- 3.36)

Actual versus Predicted Demand



Step 2 - Forecasting

Trend R-Squared Matrix

Independent Variable	3rd Ord Polynomial	2nd Ord Polynomial	Exponential	Linear	Choose Method
Temp	4%	4%	#####	11%	Linear
Rainfall	2%	1%	#####	2%	Linear
Raindays	0%	0%	#####	0%	Linear
4dWAD	0%	0%	#####	3%	

Number of Periods to Forecast: 10

Appendix I.6: Output for Model 13

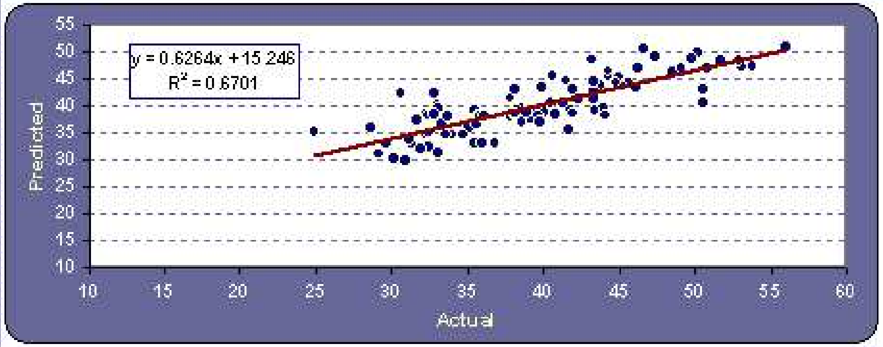
Equation Parameters		
R Square	0.7437	74.37% of the change in Demand can be explained by the change in the 4 Independent Variables
Adjusted R Square	0.7430	Adjusted for Sample Size bias
Standard Error	3.4770	to +/- on result of Regression Equation
F - Statistic	1056.3563	Therefore analysis IS Significant

2.06817	Durbin-Watson Statistic	Critical D-W Values: Lower (Dl)=1.59; Upper (Du)=1.76
	Therefore No Autocorrelation detected at 95% Confidence	
2.37802	Critical F-Statistic at 95% Confidence	(Significance holds to 100.0% Level of Confidence)

Multiple Regression Equation			Independent Analysis			Auto Correlation	Tests for Multicolinearity between Independent Variables				
	Coefficients	Standard Error	R Squared	Gradient	Intercept	Dl=1.65 Du=1.69 DW Score	Adjusted R-Squared against other Indep	Independent R-Square Matrix			
Intercept	-1.372	0.835									
MAD	0.979	0.021	72.50%	1.06	-2.54			100%	25%	11%	5%
Temp	0.109	0.021	22.63%	0.63	25.00			25%	100%	0%	0%
Restrict	0.002	0.158	6.89%	-2.90	44.17			11%	0%	100%	0%
RainWeight	-1.054	0.114	8.93%	-2.51	40.54			5%	0%	0%	100%
								MAD	Temp	Restrict	RainWeight

Demand = 0.98*MAD + 0.11*Temp + 0.00*Restrict + -1.05*RainWeight + -1.37 (+/- 3.48)

Actual versus Predicted Demand



Step 2 - Forecasting

Trend R-Squared Matrix Independent Variable	3rd Ord Polynomial	2nd Ord Polynomial	Exponential	Linear	Choose Method
					Linear
					Linear
					Linear

Number of Periods to Forecast: 1

Appendix I.7: Output for Model 21

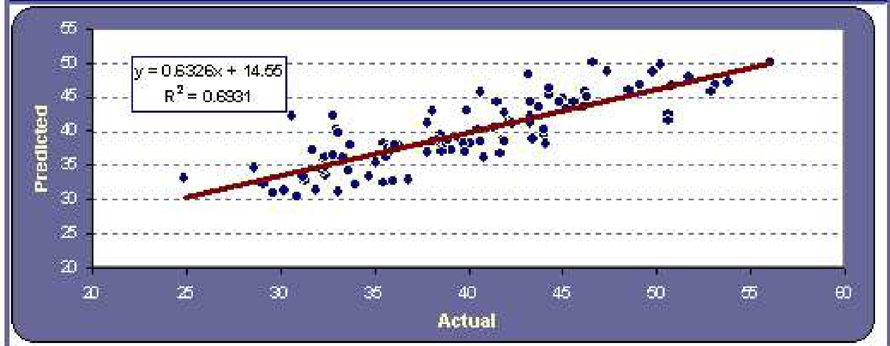
Equation Parameters					
R Square	0.7393	73.93% of the change in Demand can be explained by the change in the 4 Independent Variables			
Adjusted R Square	0.7386	Adjusted for Sample Size bias	1.99346	Durbin-Watson Statistic	Critical D-W Values: Lower (Dl)=1.59; Upper (Du)=1.76
Standard Error	3.5068	to +/- on result of Regression Equation		Therefore No Autocorrelation detected at 95% Confidence	
F - Statistic	1032.3167	Therefore analysis IS Significant	2.37802	Critical F-Statistic at 95% Confidence	(Significance holds to 100.0 % Level of Confidence)

Multiple Regression Equation	Coefficients	Standard Error	Independent Analysis: R Squared	Gradient	Intercept	Auto Correlation: Dl=1.65 Du=1.69 DW-Stat	Adjusted R-Squared against other Indep	MAD	Raindays	Restrict	TempDiff	
Intercept	-0.603	0.871										
MAD	1.017	0.020	72.50%	1.06	-2.54			100%	10%	11%	18%	MAD
Raindays	-1.909	0.235	14.20%	-5.92	41.25			10%	100%	0%	18%	Raindays
Restrict	0.135	0.158	6.89%	-2.90	44.17			11%	0%	100%	0%	Restrict
TempDiff	0.020	0.035	16.65%	0.90	29.99			18%	18%	0%	100%	TempDiff

Tests for Multicolinearity between Independent Variables — Independent R-Square Matrix

Demand = 1.02*MAD + -1.91*Raindays + 0.13*Restrict + 0.02*TempDiff + -0.60 (+/- 3.51)

Actual versus Predicted Demand



Step 2 - Forecasting

Trend R-Squared Matrix / Independent Variable	3rd Ord Polynomial	2nd Ord Polynomial	Exponential	Linear	Choose Method
					Linear
					Linear
					Linear

Number of Periods to Forecast: 10

Appendix I.8: Output for Model 22

Equation Parameters

R Square	0.7437	74.37% of the change in Demand can be explained by the change in the 4 Independent Variables
Adjusted R Square	0.7430	Adjusted for Sample Size bias
Standard Error	3.4770	to +/- on result of Regression Equation
F - Statistic	1056.3563	Therefore analysis IS Significant

2.06817	Durbin-Watson Statistic	Critical D-W Values: Lower (Dl)=1.59; Upper (Du)=1.76
	Therefore No Autocorrelation detected at 95% Confidence	
2.37802	Critical F-Statistic at 95% Confidence	(Significance holds to 100.0% Level of Confidence)

Multiple Regression Equation / **Independent Analysis** / **Auto Correlation**

	Coefficients	Standard Error	R Squared	Gradient	Intercept	Dl=1.65 Du=1.69 DW-Stat
Intercept	-1.372	0.835				
MAD	0.979	0.021	72.50%	1.06	-2.54	
Temp	0.109	0.021	22.63%	0.63	25.00	
Restrict	0.002	0.158	6.89%	-2.90	44.17	
RainWeight	-1.054	0.114	8.93%	-2.51	40.54	

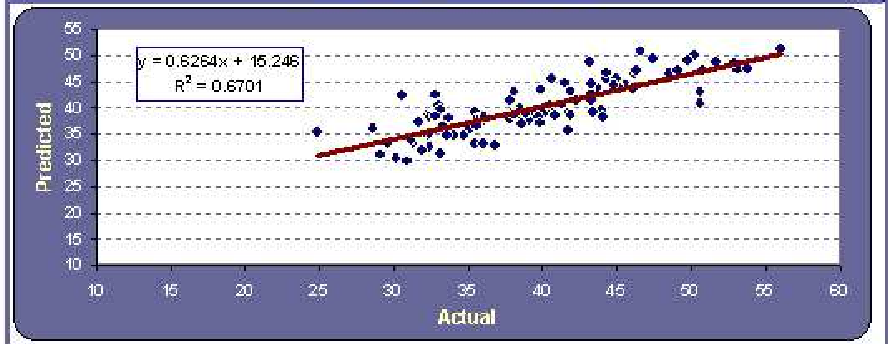
Tests for Multicolinearity between Independent Variables

Independent R-Square Matrix

Adjusted R-Squared against other Indep	MAD	Temp	Restrict	RainWeight	
	100%	25%	11%	5%	MAD
	25%	100%	0%	0%	Temp
	11%	0%	100%	0%	Restrict
	5%	0%	0%	100%	RainWeight

Demand = 0.98*MAD + 0.11*Temp + 0.00*Restrict + -1.05*RainWeight + -1.37 (+/- 3.48)

Actual versus Predicted Demand



Step 2 - Forecasting

Trend R-Squared Matrix / Independent Variable	3rd Ord Polynomial	2nd Ord Polynomial	Exponential	Linear	Choose Method
					Linear
					Linear
					Linear

Number of Periods to Forecast: 1

Appendix I.9: Output for Model 25

Equation Parameters		
R Square	0.7470	74.70% of the change in Demand can be explained by the change in the 7 Independent Variables
Adjusted R Square	0.7458	Adjusted for Sample Size bias
Standard Error	3.4580	to +/- on result of Regression Equation
F - Statistic	613.0001	Therefore analysis IS Significant

2.05389	Durbin-Watson Statistic	Critical D-W Values: Lower (Dl)=1.57; Upper (Du)=1.78
	Therefore No Autocorrelation detected at 95% Confidence	
2.01584	Critical F-Statistic at 95% Confidence	(Significance holds to 100.0% Level of Confidence)

Multiple Regression Equation / Independent Analysis / Auto Correlation

	Coefficients	Standard Error	R Squared	Gradient	Intercept	Dl=1.65 Du=1.69 DW-Stat	Adjusted R-Squared against other Indep
Intercept	-0.457	0.860					
Temp	0.106	0.022	22.63%	0.63	25.00		
Raindays	-1.255	0.293	14.20%	-5.92	41.25		
MAD	0.968	0.022	72.50%	1.06	-2.54		
Restrict	0.012	0.158	6.89%	-2.90	44.17		
TempDev	0.147	0.154	19.23%	1.94	27.85		
TempDiff	-0.105	0.074	16.65%	0.90	29.99		
RainWeight	-0.677	0.151	8.93%	-2.51	40.54		

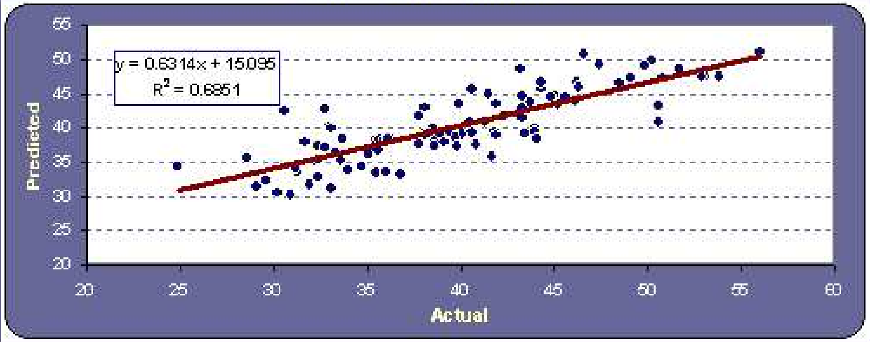
Tests for Multicolinearity between Independent Variables

Independent R-Square Matrix

	Temp	Raindays	MAD	Restrict	TempDev	TempDiff	RainWeight
Temp	100%	2%	25%	0%	25%	16%	0%
Raindays	2%	100%	10%	0%	14%	18%	45%
MAD	25%	10%	100%	11%	21%	18%	5%
Restrict	0%	0%	11%	100%	0%	0%	0%
TempDev	25%	14%	21%	0%	100%	83%	9%
TempDiff	16%	18%	18%	0%	83%	100%	13%
RainWeight	0%	45%	5%	0%	9%	13%	100%

Demand = 0.11*Temp + -1.26*Raindays + 0.97*MAD + 0.01*Restrict + 0.15*TempDev + -0.11*Temp Diff + -0.68*RainWeight + -0.46 (+/- 3.46)

Actual versus Predicted Demand



Step 2 - Forecasting

Trend R-Squared Matrix / Independent Variable	3rd Ord Polynomial	2nd Ord Polynomial	Exponential	Linear	Choose Method
					Linear
					Linear
					Linear

Number of Periods to Forecast: 10

APPENDIX J

MODEL GENERATED ACTUAL AND FORECASTED DEMAND WITH RELATED ERRORS

Appendix J: Generated Actual & Forecasted Demand with Related Error

Date	Actual Demand (ML)	Forecasted Demand – Model 12	Error – Model 12	Forecasted Demand – Model 13	Error – Model 13	Forecasted Demand – Model 25	Error – Model 25
1-Jan-04	39.30	43.38	-4.08	43.45	-4.15	46.04	-6.74
2-Jan-04	42.50	43.79	-1.29	43.85	-1.35	45.74	-3.24
3-Jan-04	42.80	43.96	-1.16	44.03	-1.23	46.49	-3.69
4-Jan-04	41.00	40.38	0.62	40.46	0.54	45.53	-4.53
5-Jan-04	39.90	43.53	-3.63	43.63	-3.73	49.27	-9.37
6-Jan-04	47.70	45.19	2.51	45.31	2.39	50.58	-2.88
7-Jan-04	51.60	47.38	4.22	47.50	4.10	51.01	0.59
8-Jan-04	51.30	46.14	5.16	46.22	5.08	47.01	4.29
9-Jan-04	46.00	49.89	-3.89	49.90	-3.90	47.38	-1.38
10-Jan-04	45.10	49.18	-4.08	49.19	-4.09	45.41	-0.31
11-Jan-04	33.50	39.17	-5.67	39.20	-5.70	38.23	-4.73
12-Jan-04	30.20	32.24	-2.04	32.34	-2.14	35.95	-5.75
13-Jan-04	33.50	35.29	-1.79	35.43	-1.93	36.45	-2.95
14-Jan-04	34.30	32.51	1.79	32.67	1.63	31.41	2.89
15-Jan-04	30.50	30.76	-0.26	30.88	-0.38	31.46	-0.96
16-Jan-04	33.90	29.82	4.08	29.99	3.91	33.00	0.90
17-Jan-04	29.00	28.81	0.19	29.00	0.00	31.74	-2.74
18-Jan-04	46.00	32.17	13.84	32.37	13.63	34.23	11.77
19-Jan-04	30.90	31.75	-0.85	31.87	-0.97	33.30	-2.40
20-Jan-04	33.00	34.16	-1.16	34.27	-1.27	36.24	-3.24
21-Jan-04	33.70	37.66	-3.96	37.75	-4.05	38.95	-5.25
22-Jan-04	32.80	35.17	-2.37	35.32	-2.52	38.06	-5.26
23-Jan-04	39.00	37.04	1.96	37.18	1.82	38.95	0.05
24-Jan-04	35.50	37.92	-2.42	38.07	-2.57	40.87	-5.37
25-Jan-04	36.20	38.55	-2.35	38.70	-2.50	41.90	-5.69
26-Jan-04	37.00	36.72	0.28	36.88	0.12	39.59	-2.59
27-Jan-04	43.00	39.99	3.01	40.10	2.90	40.94	2.06
28-Jan-04	39.40	41.42	-2.02	41.56	-2.16	42.67	-3.27
29-Jan-04	32.50	40.13	-7.63	40.25	-7.75	42.10	-9.60
30-Jan-04	38.70	35.74	2.96	35.84	2.86	38.42	0.28
31-Jan-04	37.90	36.17	1.73	36.29	1.61	37.60	0.30
1-Feb-04	39.20	36.76	2.44	36.88	2.32	38.61	0.59
2-Feb-04	37.10	39.48	-2.38	39.54	-2.44	38.22	-1.11
3-Feb-04	32.30	29.64	2.66	29.68	2.62	33.90	-1.60
4-Feb-04	33.40	33.92	-0.52	34.00	-0.60	35.13	-1.73
5-Feb-04	34.20	36.08	-1.88	36.18	-1.98	37.32	-3.11
6-Feb-04	35.30	35.76	-0.46	35.87	-0.57	38.50	-3.20
7-Feb-04	37.50	36.95	0.55	37.06	0.44	39.47	-1.97
8-Feb-04	30.60	36.50	-5.90	36.61	-6.01	41.58	-10.98
9-Feb-04	45.30	39.30	6.00	39.41	5.89	43.40	1.90
10-Feb-04	39.20	40.41	-1.21	40.53	-1.33	45.06	-5.86
11-Feb-04	47.80	42.56	5.24	42.65	5.15	45.85	1.95
12-Feb-04	43.20	45.49	-2.29	45.57	-2.37	47.89	-4.69

Appendix J (cont'd): Generated Actual & Forecasted Demand with Related Error

Date	Actual Demand (ML)	Forecasted Demand – Model 12	Error – Model 12	Forecasted Demand – Model 13	Error – Model 13	Forecasted Demand – Model 25	Error – Model 25
13-Feb-04	44.00	45.36	-1.36	45.45	-1.45	48.69	-4.69
14-Feb-04	44.70	46.14	-1.44	46.19	-1.49	48.59	-3.88
15-Feb-04	44.10	45.74	-1.64	45.83	-1.73	48.78	-4.68
16-Feb-04	50.70	47.74	2.96	47.83	2.87	49.63	1.08
17-Feb-04	43.80	46.34	-2.54	46.34	-2.54	48.20	-4.40
18-Feb-04	44.70	47.14	-2.44	47.19	-2.49	50.09	-5.39
19-Feb-04	41.80	47.08	-5.28	47.16	-5.36	51.18	-9.38
20-Feb-04	50.20	47.21	2.99	47.31	2.89	51.14	-0.94
21-Feb-04	47.10	48.19	-1.09	48.30	-1.20	51.25	-4.15
22-Feb-04	48.80	49.10	-0.30	49.21	-0.41	50.48	-1.68
23-Feb-04	50.90	50.55	0.35	50.60	0.30	49.43	1.47
24-Feb-04	43.70	42.79	0.91	42.79	0.91	42.11	1.59
25-Feb-04	37.90	46.18	-8.28	46.21	-8.31	44.72	-6.82
26-Feb-04	36.10	40.25	-4.15	40.31	-4.21	41.00	-4.90
27-Feb-04	36.30	37.82	-1.52	37.92	-1.62	40.91	-4.61
28-Feb-04	36.60	38.61	-2.01	38.71	-2.11	41.67	-5.07
29-Feb-04	40.20	39.34	0.86	39.45	0.75	42.57	-2.37
1-Mar-04	40.30	39.89	0.41	39.97	0.33	42.70	-2.40
2-Mar-04	39.70	40.29	-0.59	40.34	-0.64	41.98	-2.28
3-Mar-04	41.00	41.12	-0.12	41.15	-0.15	41.46	-0.46
4-Mar-04	43.70	42.00	1.70	42.03	1.67	40.88	2.82
5-Mar-04	33.00	40.07	-7.07	40.09	-7.09	40.02	-7.02
6-Mar-04	33.60	28.12	5.48	28.17	5.43	35.66	-2.06
7-Mar-04	34.70	35.06	-0.36	35.16	-0.46	37.74	-3.04
8-Mar-04	39.90	35.61	4.29	35.78	4.12	39.64	0.26
9-Mar-04	36.00	38.60	-2.60	38.75	-2.75	40.52	-4.52
10-Mar-04	39.70	39.85	-0.15	39.98	-0.28	40.50	-0.80
11-Mar-04	37.80	39.56	-1.76	39.61	-1.81	39.53	-1.73
12-Mar-04	35.00	38.86	-3.86	38.95	-3.95	40.69	-5.69
13-Mar-04	34.60	38.68	-4.08	38.79	-4.19	40.53	-5.93
14-Mar-04	38.00	38.09	-0.09	38.19	-0.19	39.39	-1.39
15-Mar-04	43.00	39.45	3.55	39.55	3.45	39.53	3.47
16-Mar-04	34.90	39.45	-4.55	39.54	-4.64	39.81	-4.91
17-Mar-04	34.40	36.73	-2.33	36.83	-2.43	38.14	-3.74
18-Mar-04	34.80	38.54	-3.74	38.63	-3.83	38.81	-4.01
19-Mar-04	36.80	31.75	5.05	31.84	4.96	35.10	1.70
20-Mar-04	33.70	36.44	-2.74	36.52	-2.82	38.16	-4.46
21-Mar-04	31.90	36.09	-4.19	36.19	-4.29	38.17	-6.27
22-Mar-04	41.90	37.47	4.43	37.54	4.36	38.36	3.54
23-Mar-04	36.60	37.30	-0.70	37.37	-0.77	38.61	-2.01
24-Mar-04	33.90	34.98	-1.08	35.06	-1.16	38.13	-4.23
25-Mar-04	35.90	38.28	-2.38	38.34	-2.44	39.99	-4.09
26-Mar-04	40.70	38.27	2.43	38.34	2.36	40.27	0.43

Appendix J (cont'd): Generated Actual & Forecasted Demand with Related Error

Date	Actual Demand (ML)	Forecasted Demand – Model 12	Error – Model 12	Forecasted Demand – Model 13	Error – Model 13	Forecasted Demand – Model 25	Error – Model 25
27-Mar-04	35.80	38.05	-2.25	38.12	-2.32	39.76	-3.96
28-Mar-04	36.50	38.35	-1.85	38.40	-1.90	40.37	-3.86
29-Mar-04	39.50	36.38	3.12	36.44	3.06	38.59	0.91
30-Mar-04	36.60	38.48	-1.88	38.55	-1.95	41.12	-4.52
31-Mar-04	40.20	39.76	0.44	39.84	0.36	42.15	-1.95
1-Apr-04	40.30	40.89	-0.59	40.97	-0.67	43.13	-2.83
2-Apr-04	39.90	40.64	-0.74	40.70	-0.80	42.62	-2.72
3-Apr-04	38.60	40.89	-2.29	40.94	-2.34	42.61	-4.01
4-Apr-04	38.70	40.39	-1.69	40.43	-1.73	42.56	-3.85
5-Apr-04	42.20	38.44	3.76	38.49	3.71	41.22	0.98
6-Apr-04	40.70	38.50	2.21	38.54	2.16	40.47	0.23
7-Apr-04	38.90	40.86	-1.96	40.89	-1.99	41.17	-2.26
8-Apr-04	38.30	40.89	-2.59	40.92	-2.62	41.20	-2.90
9-Apr-04	35.50	36.94	-1.44	37.00	-1.50	39.38	-3.88
10-Apr-04	36.90	38.52	-1.62	38.57	-1.67	40.62	-3.72
11-Apr-04	35.60	37.81	-2.21	37.87	-2.27	40.58	-4.98
12-Apr-04	37.80	38.08	-0.28	38.17	-0.37	41.91	-4.11
13-Apr-04	42.50	39.88	2.62	39.96	2.54	42.53	-0.03
14-Apr-04	38.20	39.92	-1.72	39.98	-1.78	41.83	-3.63
15-Apr-04	41.30	40.87	0.43	40.91	0.39	41.61	-0.31
16-Apr-04	39.60	41.22	-1.62	41.26	-1.66	42.66	-3.06
17-Apr-04	36.70	37.38	-0.68	37.42	-0.72	40.47	-3.77
18-Apr-04	37.20	37.94	-0.74	38.04	-0.84	42.64	-5.44
19-Apr-04	42.90	40.17	2.73	40.22	2.68	42.13	0.77
20-Apr-04	41.20	38.21	2.99	38.28	2.92	41.60	-0.40
21-Apr-04	41.00	41.52	-0.52	41.56	-0.56	43.49	-2.49
22-Apr-04	38.40	39.16	-0.76	39.19	-0.79	41.90	-3.50
23-Apr-04	42.40	41.72	0.68	41.76	0.64	43.68	-1.28
24-Apr-04	40.40	41.75	-1.35	41.81	-1.41	44.52	-4.12
25-Apr-04	39.00	41.47	-2.47	41.54	-2.54	43.90	-4.90
26-Apr-04	42.10	41.70	0.40	41.73	0.37	42.33	-0.23
27-Apr-04	42.90	38.01	4.89	38.03	4.87	37.68	5.22
28-Apr-04	37.40	39.90	-2.50	39.85	-2.45	38.05	-0.65
29-Apr-04	34.20	35.01	-0.81	35.00	-0.80	34.88	-0.68
30-Apr-04	34.40	35.17	-0.77	35.19	-0.79	36.36	-1.96
1-May-04	34.50	36.21	-1.71	36.26	-1.76	38.95	-4.45
2-May-04	34.90	35.54	-0.64	35.59	-0.69	39.10	-4.20
3-May-04	34.40	35.55	-1.15	35.60	-1.20	39.95	-5.55
4-May-04	41.20	37.32	3.88	37.37	3.83	40.16	1.04
5-May-04	41.30	39.02	2.28	39.07	2.23	40.66	0.64
6-May-04	36.40	39.06	-2.66	39.08	-2.68	39.37	-2.97
7-May-04	38.00	39.62	-1.62	39.63	-1.63	39.36	-1.36
8-May-04	34.80	35.32	-0.52	35.33	-0.53	36.52	-1.72
9-May-04	31.80	33.90	-2.10	33.96	-2.16	38.49	-6.69

Appendix J (cont'd): Generated Actual & Forecasted Demand with Related Error

Date	Actual Demand (ML)	Forecasted Demand – Model 12	Error – Model 12	Forecasted Demand – Model 13	Error – Model 13	Forecasted Demand – Model 25	Error – Model 25
10-May-04	39.10	36.88	2.22	36.92	2.18	39.61	-0.51
11-May-04	40.00	37.28	2.72	37.32	2.68	40.53	-0.53
12-May-04	38.20	37.61	0.59	37.61	0.59	40.55	-2.35
13-May-04	38.40	39.35	-0.95	39.36	-0.96	42.40	-4.00
14-May-04	40.00	39.77	0.23	39.78	0.22	43.03	-3.03
15-May-04	39.40	39.86	-0.46	39.90	-0.50	43.08	-3.68
16-May-04	39.00	39.90	-0.90	39.93	-0.93	43.12	-4.12
17-May-04	44.10	41.11	2.99	41.12	2.98	43.22	0.88
18-May-04	40.40	41.47	-1.07	41.50	-1.10	44.15	-3.75
19-May-04	40.70	41.58	-0.87	41.59	-0.89	43.04	-2.34
20-May-04	39.40	41.34	-1.94	41.33	-1.93	42.54	-3.14
21-May-04	40.50	40.95	-0.45	40.97	-0.47	43.21	-2.71
22-May-04	38.50	39.74	-1.24	39.72	-1.22	41.20	-2.69
23-May-04	36.90	39.37	-2.47	39.39	-2.49	41.49	-4.59
24-May-04	42.10	40.05	2.05	40.07	2.04	40.48	1.62
25-May-04	40.20	39.89	0.31	39.90	0.30	39.28	0.92
26-May-04	35.70	36.22	-0.52	36.21	-0.51	36.39	-0.69
27-May-04	31.70	34.39	-2.69	34.38	-2.68	35.30	-3.60
28-May-04	35.60	36.00	-0.40	36.00	-0.40	38.92	-3.32
29-May-04	36.00	34.96	1.04	34.96	1.04	38.55	-2.55
30-May-04	33.80	35.11	-1.31	35.15	-1.35	39.75	-5.95
31-May-04	41.20	37.28	3.92	37.30	3.90	40.37	0.83
1-Jun-04	37.70	37.78	-0.08	37.80	-0.10	40.32	-2.62
2-Jun-04	39.40	38.62	0.78	38.64	0.76	40.30	-0.90
3-Jun-04	36.90	39.64	-2.74	39.67	-2.77	40.65	-3.75
4-Jun-04	38.20	38.40	-0.20	38.41	-0.21	39.57	-1.37
5-Jun-04	38.10	38.35	-0.24	38.34	-0.24	39.71	-1.61
6-Jun-04	36.20	37.67	-1.47	37.68	-1.48	40.40	-4.20
7-Jun-04	39.50	38.09	1.41	38.08	1.42	39.88	-0.37
8-Jun-04	34.90	37.73	-2.83	37.75	-2.85	40.83	-5.93
9-Jun-04	43.40	38.98	4.42	38.99	4.41	40.02	3.39
10-Jun-04	38.50	39.65	-1.15	39.67	-1.17	41.02	-2.52
11-Jun-04	37.60	36.42	1.18	36.43	1.17	38.38	-0.78
12-Jun-04	34.00	38.44	-4.44	38.43	-4.43	41.54	-7.54
13-Jun-04	41.20	38.45	2.75	38.47	2.73	41.28	-0.08
14-Jun-04	35.90	38.11	-2.21	38.16	-2.26	41.70	-5.80
15-Jun-04	42.90	39.27	3.63	39.30	3.60	40.65	2.26
16-Jun-04	38.40	39.37	-0.97	39.33	-0.93	40.51	-2.11
17-Jun-04	37.30	38.34	-1.04	38.30	-1.00	40.37	-3.07
18-Jun-04	34.30	37.99	-3.69	37.96	-3.66	40.66	-6.36
19-Jun-04	38.30	37.39	0.91	37.39	0.91	40.21	-1.91
20-Jun-04	36.70	36.02	0.69	35.96	0.74	38.17	-1.47
21-Jun-04	36.60	36.36	0.24	36.34	0.26	40.46	-3.86
22-Jun-04	38.70	37.64	1.06	37.63	1.07	40.94	-2.24

Appendix J (cont'd): Generated Actual & Forecasted Demand with Related Error

Date	Actual Demand (ML)	Forecasted Demand – Model 12	Error – Model 12	Forecasted Demand – Model 13	Error – Model 13	Forecasted Demand – Model 25	Error – Model 25
23-Jun-04	39.00	38.00	1.00	38.00	1.00	41.81	-2.81
24-Jun-04	39.80	36.60	3.20	36.62	3.18	40.45	-0.65
25-Jun-04	40.10	39.68	0.42	39.67	0.43	41.72	-1.62
26-Jun-04	42.00	39.78	2.22	39.73	2.27	41.15	0.85
27-Jun-04	35.10	38.94	-3.84	38.90	-3.80	41.68	-6.58
28-Jun-04	40.80	39.57	1.23	39.56	1.25	42.16	-1.36
29-Jun-04	37.60	39.06	-1.46	39.06	-1.46	42.18	-4.58
30-Jun-04	38.00	38.38	-0.38	38.39	-0.39	41.82	-3.82
1-Jul-04	40.30	39.59	0.71	39.60	0.70	42.02	-1.72
2-Jul-04	41.90	39.88	2.02	39.89	2.01	42.41	-0.51
3-Jul-04	36.60	39.44	-2.84	39.44	-2.84	42.16	-5.56
4-Jul-04	38.60	40.24	-1.64	40.28	-1.68	42.82	-4.22
5-Jul-04	42.90	40.82	2.08	40.85	2.05	42.24	0.66
6-Jul-04	39.70	39.11	0.59	39.07	0.63	40.83	-1.13
7-Jul-04	38.20	39.20	-1.00	39.14	-0.94	41.05	-2.85
8-Jul-04	37.20	38.66	-1.46	38.59	-1.39	40.60	-3.40
9-Jul-04	36.20	37.92	-1.72	37.91	-1.71	41.04	-4.84
10-Jul-04	40.80	38.41	2.39	38.42	2.38	40.55	0.25
11-Jul-04	36.50	35.36	1.14	35.37	1.13	37.75	-1.25
12-Jul-04	37.80	38.51	-0.71	38.54	-0.74	41.20	-3.40
13-Jul-04	37.40	38.39	-0.99	38.39	-0.99	41.81	-4.41
14-Jul-04	40.00	38.02	1.98	38.01	1.99	41.53	-1.53
15-Jul-04	40.60	39.02	1.58	39.00	1.60	41.81	-1.21
16-Jul-04	42.30	40.05	2.25	40.03	2.27	41.56	0.74
17-Jul-04	38.00	40.21	-2.21	40.19	-2.19	42.00	-4.00
18-Jul-04	36.90	38.63	-1.73	38.56	-1.66	41.40	-4.50
19-Jul-04	37.50	38.20	-0.70	38.16	-0.66	42.52	-5.01
20-Jul-04	40.50	38.36	2.14	38.35	2.15	42.50	-2.00
21-Jul-04	41.00	39.13	1.87	39.13	1.87	42.59	-1.59
22-Jul-04	41.30	39.90	1.40	39.87	1.43	42.54	-1.24
23-Jul-04	42.20	40.98	1.22	40.94	1.26	43.54	-1.34
24-Jul-04	37.70	40.43	-2.72	40.40	-2.70	42.80	-5.10
25-Jul-04	40.70	40.86	-0.16	40.86	-0.16	42.48	-1.78
26-Jul-04	42.00	41.41	0.59	41.43	0.57	42.61	-0.61
27-Jul-04	40.90	35.96	4.94	35.88	5.02	36.44	4.46
28-Jul-04	34.10	36.62	-2.52	36.59	-2.49	39.59	-5.49
29-Jul-04	36.20	36.05	0.15	36.05	0.15	40.29	-4.09
30-Jul-04	39.90	38.09	1.81	38.09	1.81	41.03	-1.13
31-Jul-04	39.00	37.60	1.40	37.60	1.40	40.38	-1.38
1-Aug-04	36.40	38.59	-2.19	38.62	-2.22	41.19	-4.79
2-Aug-04	42.30	40.40	1.90	40.44	1.86	41.81	0.49
3-Aug-04	39.80	36.16	3.64	36.14	3.66	36.91	2.89
4-Aug-04	34.30	38.12	-3.82	38.09	-3.79	40.93	-6.63
5-Aug-04	35.60	37.86	-2.26	37.84	-2.24	40.44	-4.84

Appendix J (cont'd): Generated Actual & Forecasted Demand with Related Error

Date	Actual Demand (ML)	Forecasted Demand – Model 12	Error – Model 12	Forecasted Demand – Model 13	Error – Model 13	Forecasted Demand – Model 25	Error – Model 25
6-Aug-04	39.70	37.27	2.43	37.25	2.45	40.11	-0.41
7-Aug-04	42.30	37.76	4.54	37.73	4.57	39.88	2.42
8-Aug-04	32.20	37.38	-5.18	37.35	-5.15	40.60	-8.40
9-Aug-04	39.50	38.36	1.14	38.34	1.16	41.68	-2.18
10-Aug-04	38.10	38.01	0.09	38.00	0.10	41.34	-3.24
11-Aug-04	40.40	37.89	2.51	37.90	2.50	43.23	-2.83
12-Aug-04	40.10	39.69	0.41	39.68	0.42	43.73	-3.63
13-Aug-04	40.30	40.71	-0.41	40.75	-0.45	44.74	-4.44
14-Aug-04	51.10	42.93	8.17	42.90	8.20	43.15	7.95
15-Aug-04	35.00	40.74	-5.74	40.66	-5.66	42.33	-7.33
16-Aug-04	38.80	41.05	-2.25	41.02	-2.22	42.64	-3.84
17-Aug-04	40.70	41.30	-0.60	41.27	-0.57	41.50	-0.80
18-Aug-04	39.00	34.19	4.81	34.14	4.86	34.76	4.24
19-Aug-04	34.00	38.29	-4.29	38.28	-4.28	40.09	-6.09
20-Aug-04	34.20	37.46	-3.26	37.48	-3.28	40.63	-6.43
21-Aug-04	37.90	36.94	0.96	36.97	0.93	40.74	-2.84
22-Aug-04	37.10	36.84	0.26	36.89	0.21	41.30	-4.20
23-Aug-04	42.80	38.82	3.98	38.86	3.94	42.60	0.20
24-Aug-04	39.80	40.22	-0.42	40.25	-0.45	44.32	-4.52
25-Aug-04	41.90	41.11	0.79	41.14	0.76	44.61	-2.71
26-Aug-04	42.80	42.11	0.69	42.11	0.69	45.82	-3.02
27-Aug-04	42.10	42.12	-0.02	42.13	-0.03	45.49	-3.39
28-Aug-04	41.30	42.81	-1.51	42.84	-1.54	46.01	-4.71
29-Aug-04	50.50	44.77	5.73	44.79	5.71	44.70	5.80
30-Aug-04	36.40	43.22	-6.82	43.24	-6.84	42.93	-6.53
31-Aug-04	39.40	37.70	1.70	37.61	1.79	36.24	3.16
1-Sep-04	33.20	36.82	-3.62	36.79	-3.59	38.26	-5.06
2-Sep-04	35.40	34.28	1.12	34.32	1.08	37.51	-2.11
3-Sep-04	36.40	36.81	-0.41	36.84	-0.44	38.47	-2.07
4-Sep-04	35.80	35.95	-0.15	35.99	-0.19	38.36	-2.56
5-Sep-04	31.90	33.24	-1.34	33.30	-1.40	37.25	-5.35
6-Sep-04	37.20	34.13	3.07	34.21	2.99	37.95	-0.75
7-Sep-04	39.60	37.50	2.10	37.57	2.03	38.72	0.88
8-Sep-04	36.90	36.66	0.24	36.67	0.23	36.41	0.49
9-Sep-04	31.20	32.90	-1.70	32.89	-1.69	35.02	-3.82
10-Sep-04	34.60	33.71	0.89	33.77	0.83	37.55	-2.95
11-Sep-04	37.20	36.19	1.01	36.25	0.95	39.44	-2.24
12-Sep-04	34.70	35.00	-0.30	35.02	-0.32	38.47	-3.77
13-Sep-04	35.80	36.10	-0.30	36.12	-0.32	40.75	-4.95
14-Sep-04	38.70	37.30	1.40	37.33	1.37	41.84	-3.14
15-Sep-04	42.50	38.78	3.72	38.81	3.69	43.03	-0.53
16-Sep-04	40.10	40.05	0.05	40.08	0.02	43.20	-3.10
17-Sep-04	41.30	41.46	-0.16	41.48	-0.18	44.76	-3.46
18-Sep-04	44.20	42.67	1.53	42.69	1.51	45.18	-0.98

Appendix J (cont'd): Generated Actual & Forecasted Demand with Related Error

Date	Actual Demand (ML)	Forecasted Demand – Model 12	Error – Model 12	Forecasted Demand – Model 13	Error – Model 13	Forecasted Demand – Model 25	Error – Model 25
19-Sep-04	38.20	41.99	-3.79	42.03	-3.83	45.08	-6.88
20-Sep-04	42.80	42.36	0.44	42.38	0.42	44.89	-2.09
21-Sep-04	41.70	42.09	-0.39	42.09	-0.39	44.78	-3.08
22-Sep-04	41.20	41.65	-0.45	41.68	-0.48	44.35	-3.15
23-Sep-04	40.40	42.37	-1.97	42.40	-2.00	44.35	-3.95
24-Sep-04	43.60	43.02	0.58	42.75	0.85	44.55	-0.95
25-Sep-04	38.30	41.70	-3.40	41.40	-3.10	43.42	-5.12
26-Sep-04	37.00	41.26	-4.26	41.00	-4.00	44.89	-7.89
27-Sep-04	40.50	41.58	-1.08	41.34	-0.84	45.47	-4.97
28-Sep-04	42.00	41.46	0.54	41.24	0.76	45.75	-3.74
29-Sep-04	44.60	42.64	1.96	42.39	2.21	45.12	-0.52
30-Sep-04	42.50	43.87	-1.37	43.61	-1.11	45.36	-2.86
1-Oct-04	42.50	44.08	-1.58	43.80	-1.30	44.60	-2.10
2-Oct-04	36.50	38.97	-2.47	38.63	-2.13	41.26	-4.76
3-Oct-04	36.90	40.76	-3.86	40.48	-3.58	44.68	-7.77
4-Oct-04	39.90	40.54	-0.64	40.29	-0.39	45.15	-5.25
5-Oct-04	41.90	40.47	1.43	40.23	1.67	45.17	-3.27
6-Oct-04	45.10	42.31	2.80	42.04	3.06	46.30	-1.20
7-Oct-04	43.60	43.94	-0.34	43.67	-0.07	47.01	-3.41
8-Oct-04	45.00	45.15	-0.15	44.87	0.13	47.80	-2.80
9-Oct-04	43.60	45.02	-1.42	44.70	-1.10	47.61	-4.01
10-Oct-04	38.80	43.39	-4.59	43.08	-4.28	46.80	-8.00
11-Oct-04	46.10	44.12	1.98	43.81	2.29	47.72	-1.62
12-Oct-04	41.40	43.78	-2.38	43.50	-2.10	48.42	-7.02
13-Oct-04	46.00	44.58	1.42	44.32	1.68	48.97	-2.97
14-Oct-04	48.40	46.87	1.53	46.60	1.80	49.33	-0.93
15-Oct-04	43.60	46.65	-3.05	46.41	-2.81	47.47	-3.87
16-Oct-04	45.10	46.28	-1.18	45.95	-0.85	44.72	0.38
17-Oct-04	39.10	43.66	-4.56	43.28	-4.18	41.76	-2.65
18-Oct-04	33.90	37.05	-3.15	36.70	-2.80	37.41	-3.51
19-Oct-04	33.40	36.39	-2.99	36.14	-2.74	37.93	-4.53
20-Oct-04	36.30	34.35	1.95	34.09	2.21	36.96	-0.66
21-Oct-04	36.20	33.68	2.52	33.42	2.78	36.66	-0.46
22-Oct-04	34.10	34.34	-0.24	34.16	-0.06	38.11	-4.01
23-Oct-04	36.70	38.87	-2.17	38.72	-2.02	41.84	-5.14
24-Oct-04	37.60	39.35	-1.75	39.20	-1.60	42.84	-5.24
25-Oct-04	38.40	36.90	1.50	36.75	1.65	41.81	-3.41
26-Oct-04	38.80	37.35	1.45	37.13	1.67	42.54	-3.74
27-Oct-04	41.20	41.44	-0.24	41.25	-0.05	44.96	-3.76
28-Oct-04	43.90	41.82	2.08	41.55	2.35	43.66	0.24
29-Oct-04	42.60	42.33	0.27	42.02	0.58	44.43	-1.83
30-Oct-04	38.20	41.76	-3.56	41.43	-3.23	43.89	-5.69
31-Oct-04	38.90	41.70	-2.80	41.40	-2.50	44.92	-6.02
1-Nov-04	43.80	41.98	1.82	41.70	2.10	43.95	-0.15

Appendix J (cont'd): Generated Actual & Forecasted Demand with Related Error

Date	Actual Demand (ML)	Forecasted Demand – Model 12	Error – Model 12	Forecasted Demand – Model 13	Error – Model 13	Forecasted Demand – Model 25	Error – Model 25
2-Nov-04	40.40	41.99	-1.59	41.75	-1.35	43.65	-3.25
3-Nov-04	43.40	40.78	2.62	40.54	2.86	40.90	2.50
4-Nov-04	33.90	38.30	-4.40	38.07	-4.17	37.96	-4.06
5-Nov-04	35.50	39.79	-4.29	39.53	-4.03	39.09	-3.58
6-Nov-04	33.60	34.24	-0.64	34.00	-0.40	34.27	-0.67
7-Nov-04	28.50	31.83	-3.33	31.63	-3.13	34.39	-5.89
8-Nov-04	35.40	32.87	2.53	32.68	2.72	35.76	-0.36
9-Nov-04	33.40	29.24	4.16	29.03	4.37	33.75	-0.35
10-Nov-04	38.60	32.94	5.66	32.72	5.88	35.14	3.46
11-Nov-04	32.80	36.94	-4.14	36.72	-3.92	38.70	-5.90
12-Nov-04	37.00	34.91	2.09	34.72	2.28	37.11	-0.11
13-Nov-04	33.60	38.40	-4.80	38.24	-4.64	41.09	-7.49
14-Nov-04	35.80	36.84	-1.04	36.62	-0.82	40.04	-4.24
15-Nov-04	37.10	38.07	-0.97	37.86	-0.76	42.05	-4.95
16-Nov-04	38.50	38.60	-0.10	38.40	0.10	41.69	-3.19
17-Nov-04	41.90	39.98	1.92	39.74	2.16	41.26	0.64
18-Nov-04	40.40	40.92	-0.52	40.67	-0.27	40.90	-0.50
19-Nov-04	34.50	40.46	-5.96	40.22	-5.72	40.43	-5.93
20-Nov-04	39.80	40.57	-0.77	40.30	-0.50	39.71	0.09
21-Nov-04	31.00	33.40	-2.40	33.12	-2.12	33.89	-2.89
22-Nov-04	31.00	32.30	-1.30	32.04	-1.04	34.41	-3.41
23-Nov-04	35.20	32.90	2.30	32.65	2.55	36.11	-0.91
24-Nov-04	36.20	34.95	1.25	34.71	1.49	38.15	-1.95
25-Nov-04	35.80	36.02	-0.22	35.77	0.03	39.04	-3.24
26-Nov-04	38.60	37.80	0.81	37.53	1.07	40.85	-2.25
27-Nov-04	37.20	38.58	-1.38	38.33	-1.13	42.03	-4.83
28-Nov-04	38.60	39.67	-1.07	39.45	-0.85	44.79	-6.19
29-Nov-04	40.90	41.23	-0.33	41.03	-0.13	46.77	-5.87
30-Nov-04	42.70	42.35	0.35	42.16	0.54	47.10	-4.40
1-Dec-04	48.60	44.93	3.67	44.72	3.88	47.38	1.22
2-Dec-04	46.00	45.71	0.30	45.42	0.58	45.71	0.29
3-Dec-04	40.70	42.71	-2.01	42.41	-1.71	42.72	-2.01
4-Dec-04	39.90	44.15	-4.25	43.82	-3.92	42.52	-2.62
5-Dec-04	36.60	40.91	-4.31	40.57	-3.97	39.14	-2.54
6-Dec-04	36.30	39.69	-3.39	39.42	-3.12	39.17	-2.87
7-Dec-04	30.70	32.88	-2.18	32.65	-1.95	34.90	-4.20
8-Dec-04	32.90	32.34	0.56	32.11	0.79	33.42	-0.52
9-Dec-04	33.50	35.42	-1.92	35.20	-1.70	36.24	-2.74
10-Dec-04	33.50	30.27	3.23	30.04	3.46	32.04	1.46
11-Dec-04	32.10	31.04	1.06	30.86	1.24	34.42	-2.32
12-Dec-04	33.80	36.25	-2.45	36.10	-2.30	39.55	-5.75
13-Dec-04	38.00	37.59	0.41	37.45	0.55	40.99	-2.99
14-Dec-04	36.20	35.56	0.64	35.42	0.78	40.35	-4.15
15-Dec-04	42.00	39.64	2.36	39.43	2.57	42.02	-0.02

Appendix J (cont'd): Generated Actual & Forecasted Demand with Related Error

Date	Actual Demand (ML)	Forecasted Demand – Model 12	Error – Model 12	Forecasted Demand – Model 13	Error – Model 13	Forecasted Demand – Model 25	Error – Model 25
16-Dec-04	38.40	39.93	-1.53	39.66	-1.26	41.49	-3.09
17-Dec-04	39.60	41.07	-1.47	40.85	-1.25	43.66	-4.06
18-Dec-04	40.70	39.02	1.68	38.76	1.94	41.34	-0.64
19-Dec-04	36.30	40.85	-4.55	40.63	-4.33	43.51	-7.21
20-Dec-04	41.70	39.64	2.06	39.46	2.24	43.40	-1.70
21-Dec-04	39.30	37.72	1.58	37.42	1.88	40.49	-1.19
22-Dec-04	38.40	40.76	-2.36	40.52	-2.12	42.97	-4.57
23-Dec-04	41.10	39.05	2.05	38.84	2.26	39.78	1.32
24-Dec-04	41.20	41.42	-0.22	41.16	0.04	39.45	1.75
25-Dec-04	35.60	37.93	-2.33	37.67	-2.07	36.21	-0.60
26-Dec-04	28.80	32.99	-4.19	32.77	-3.97	34.36	-5.56
27-Dec-04	30.80	36.70	-5.90	36.52	-5.72	37.72	-6.92
28-Dec-04	30.20	30.44	-0.24	30.24	-0.04	32.95	-2.75
29-Dec-04	32.70	32.83	-0.13	32.63	0.07	36.73	-4.03
30-Dec-04	35.80	34.51	1.29	34.31	1.49	37.68	-1.88
31-Dec-04	35.50	35.83	-0.33	35.63	-0.13	39.32	-3.82

APPENDIX K

TCC WATER RESTRICTION POLICY

Appendix K: TCC Water Restriction Policy

	Level 1	Level 2	Level 3	Level 4	Level 5
Jseable Storage Trigger oint to Introduce Restrictions	> 55%	55% to 40%	40% to 30%	30% to 20%	< 20%
Jseable Storage Trigger Point to Lift Restrictions		65%	50%	40%	30%
. LAWNS AND NEW TURF					
.1 Lawns					
.1.1 Hand held hose	Permitted.	Odd or unnumbered properties Tuesday, Thursday and Saturday - 7am to 9am and 5pm to 7pm. Even numbered properties Wednesday, Friday and Sunday - 7am to 9am and 5pm to 7pm.	Not permitted.	Not permitted.	Not permitted.
.1.2 Watering Systems not Approved by Council (Sprinkler, soaker hose, microspray etc.)	Odd or unnumbered properties Tuesday, Thursday and Saturday - 7am to 9am and 5pm to 7pm. Even numbered properties Wednesday, Friday and Sunday - 7am to 9am and 5pm to 7pm.	Not permitted	Not permitted	Not permitted	Not permitted

Appendix K (cont'd): TCC Water Restriction Policy

	Level 1	Level 2	Level 3	Level 4	Level 5
.1.3 Water Truck/Mobile Tank sourcing water from Council's water supply.	Permitted	Permitted	Not Permitted	Not Permitted	Not Permitted
.2 New Turf	Subject to the approval of the Director of Engineering Services -Two hours per day on days not permitted by Item 1.1.2. Times to be nominated.	Subject to the approval of the Director of Engineering Services -Two hours per day. Times to be nominated.	Subject to the approval of the Director of Engineering Services – New buildings - maximum of two hours per day. Times to be nominated. Renovations –Times subject to onsite inspection. Landscape alterations – not permitted when dam useable storage is less than 35%.	Not permitted.	Not permitted
. PRIVATE GARDENS					
.1 Hand-held hosing/ bucket watering	Permitted	Permitted	Hand-held hosing/bucket watering of gardens during the following times: Odd or unnumbered properties Tuesday, Thursday and Saturday – 7am to 9am and 5pm to 7pm. Even numbered properties Wednesday, Friday and Sunday – 7am to 9am and 5pm to 7pm.	Hand held hosing not permitted. Bucket watering of gardens during the following times: Odd or unnumbered properties Tuesday, Thursday and Saturday – 7am to 9am and 5pm to 7pm. Even numbered	Watering of private gardens not permitted.

Appendix K (cont'd): TCC Water Restriction Policy

	Level 1	Level 2	Level 3	Level 4	Level 5
				properties Wednesday, Friday and Sunday – 7am to 9am and 5pm to 7pm. (Not as per current fridge	
.2 **Watering systems not approved by Council (Sprinkler, soaker hose, microspray etc.)**	Odd or unnumbered properties Tuesday Thursday and Saturday - 7am to 9am and 5pm to 7pm Even numbered properties Wednesday, Friday and Sunday - 7am to 9am and 5pm to 7pm	Not permitted.	Not permitted.	Not permitted	Not permitted
.3 **Council approved drip irrigation systems**	Permitted anytime Tuesday to Sunday	Odd or unnumbered properties Tuesday Thursday and Saturday - 5am to 9am and 5pm to 9pm Even numbered properties Wednesday, Friday and Sunday - 5am to 9am and 5pm to 9pm	Odd or unnumbered properties Tuesday Thursday and Saturday - 7am to 9am and 5pm to 7pm Even numbered properties Wednesday, Friday and Sunday - 7am to 9am and 5pm to 7pm	Odd or unnumbered properties Tuesday and Saturday - 5pm to 7pm Even numbered properties Wednesday, and Sunday - 5pm to 7pm	Not permitted
.4 **Water Truck/Mobile Tank sourcing water from Council's water supply.**	Permitted	Permitted	Not Permitted	Not Permitted	Not Permitted
.5 **Carnival of Flowers or Exhibition Gardens**	As per Items 1.1.1, 1.1.2, 2.1 and 2.2.	Application for exemption to water restrictions Maximum permitted – 2 watering devices 2 hours a	Application for exemption to water restrictions. Maximum permitted – Hand held hosing 2 hours	No exemption	No exemption

Appendix K (cont'd): TCC Water Restriction Policy

	Level 1	Level 2	Level 3	Level 4	Level 5
		day on designated days.	a day Tuesday to Sunday		
.6 Persons with special circumstances	As per Items 1.1.1, 1.1.2, 2.1 and 2.2.	Maximum of 6 hours a week with 2 watering devices.	Maximum of 3 hours a week with 2 watering devices or variation to hand held watering times.	No exemption	No exemption
. WATER TOYS	Permitted	Permitted	Water toys must not be used.	Water toys must not be used.	Water toys must not be used.
. PARKS AND PUBLIC GARDENS	Watered in accordance with requirements outlined in a Water Conservation (Management) Plan approved by Council and submitted to EAC for comment.	Watered in accordance with requirements outlined in a Water Conservation (Management) Plan approved by Council and submitted to EAC for comment.	Watered in accordance with requirements outlined in a Water Conservation (Management) Plan approved by Council and submitted to EAC for comment.	Watered in accordance with requirements outlined in a Water Conservation (Management) Plan approved by Council and submitted to EAC for comment.	No exemption
. SPORTS FIELDS	Maximum of 12 hours a week with sprinklers. Watered in accordance with requirements outlined in a Water Conservation Plan approved by Council and submitted to EAC for comment.	Maximum of 6 hours a week with sprinklers. Watered in accordance with requirements outlined in a Water Conservation Plan approved by Council and submitted to EAC for comment.	Maximum of 3 hours a week with sprinklers. Watered in accordance with requirements outlined in a Water Conservation Plan approved by Council and submitted to EAC for comment.	Maximum of 1 hour a week with sprinklers. Watered in accordance with requirements outlined in a Water Conservation Plan approved by Council and submitted to EAC for comment.	Not permitted
. SCHOOLS	Maximum of 24 hours a week with sprinklers. Watered in accordance with requirements outlined in a Water Conservation Plan approved by Council and submitted to EAC for comment.	Maximum of 12 hours a week with sprinklers. Watered in accordance with requirements outlined in a Water Conservation Plan approved by Council and submitted to EAC for comment.	Maximum of 6 hours a week with sprinklers. Watered in accordance with requirements outlined in a Water Conservation Plan approved by Council and submitted to EAC for comment.	Maximum of 2 hours a week with sprinklers. Watered in accordance with requirements outlined in a Water Conservation Plan approved by Council and submitted to EAC	Not permitted

Appendix K (cont'd): TCC Water Restriction Policy

	Level 1	Level 2	Level 3	Level 4	Level 5
				for comment.	
NURSERIES CONNECTED TO COUNCIL'S WATER SUPPLY	Permitted	Permitted	Watered in accordance with requirements outlined in a Water Conservation Plan approved by Council and submitted to EAC for comment.	Watered in accordance with requirements outlined in a Water Conservation Plan approved by Council and submitted to EAC for comment.	Watered in accordance with requirements outlined in a Water Conservation Plan approved by Council and submitted to EAC for comment.
LANDSCAPE CONTRACTORS	Permitted	Permitted	Watering of plants on the day of planting using hand held hose Subject to Council's general approval.	Watering of plants on the day of planting using a bucket. Subject to Council's general approval.	Not permitted
PAVED AREAS	Permitted	Water must not be used to clean paved areas without Council approval. Council approval may be granted in the case of: (a) an accident, fire health hazard or other emergency; (b) an identifiable safety hazard that has developed; or (c) construction or renovation work to the areas.	Water must not be used to clean paved areas without Council approval. Council approval may be granted in the case of: (a) an accident, fire health hazard or other emergency; (b) an identifiable safety hazard that has developed; or (c) construction of new paved areas.	Water must not be used to clean paved areas without Council approval. Council approval may be granted in the case of: (a) an accident, fire health hazard or other emergency; (b) an identifiable safety hazard that has developed; or (c) construction of new paved areas. Water must not be used to form an exposed aggregate finish, unless from an alternative water source.	Water must not be used to clean paved areas without Council approval. Council approval may be granted in the case of: (a) an accident, fire health hazard or other emergency; (b) an identifiable safety hazard that has developed; or (c) construction of new paved areas. Water must not be used to form an exposed aggregate finish, unless from an alternative water source.

Appendix K (cont'd): TCC Water Restriction Policy

	Level 1	Level 2	Level 3	Level 4	Level 5
0. POOLS AND EXTERNAL SPAS					
0.1 Public & School Pools & External Spas	Permitted	Pools must not be filled without Council permission. Pools may be topped up with reticulated water. Pool owners are encouraged to keep their pool covered when not in use.	Pools must not be filled without Council permission. Pools may be topped up with reticulated water. Pool owners are encouraged to keep their pool covered when not in use.	Pools must not be filled unless from an alternative water source. Pools may be topped up with reticulated water. Pool owners are encouraged to keep their pool covered when not in use.	Pools must not be filled unless from an alternative water source. Pools must not be topped up unless from an alternative water source.
0.2 Private Pools and External Spas	Permitted	Pools must not be filled without Council permission. Pools may be topped up with reticulated water. Pool owners are encouraged to keep their pool covered when not in use.	Pools must not be filled without Council permission. Pools may be topped up with reticulated water. Pool owners are encouraged to keep their pool covered when not in use.	Pools must not be filled unless from an alternative water source. Pools must not be topped up unless from an alternative water source. Pool owners are encouraged to keep their pool covered when not in use.	Pools must not be filled unless from an alternative water source. Pools must not be topped up unless from an alternative water source. Pool owners are encouraged to keep their pool covered when not in use.
1. PONDS AND FOUNTAINS	Permitted	Permitted	Ponds must not be filled and fountains that do not recycle water must not be operated.	Ponds and Fountains must not be filled unless from an alternative water source.	Ponds and Fountains must not be filled unless from an alternative water source.

Appendix K (cont'd): TCC Water Restriction Policy

	Level 1	Level 2	Level 3	Level 4	Level 5
12. TANKS	Permitted	Permitted	Must not be filled or topped up unless water is used entirely for domestic purposes.	Must not be filled or topped up unless water is used entirely for domestic purposes.	Must not be filled or topped up unless water is used entirely for domestic purposes.
13. MOTOR VEHICLES, TRUCKS, BOATS ETC.WASHING					
13.1 Motor Vehicles, Caravans, Boats etc.	Permitted	Permitted	Bucket filled directly from a tap. Rinsed with water from a hose fitted with a trigger nozzle. Flushing of inboard and outboards motors to prevent corrosion is permitted.	Water must not be used to clean vehicles except to clean windscreens, windows and mirrors and then only using water from a bucket filled directly from a tap. Flushing of inboard and outboards motors to prevent corrosion is permitted.	Water must not be used to clean vehicles except to clean windscreens, windows and mirrors and then only using water from a bucket filled directly from a tap. Flushing of inboard and outboards motors to prevent corrosion is permitted.
13.2 Commercial Car Washing	Permitted	Permitted	A permanent bay car wash must not operate unless: a) the standard cycle uses 80 litres or less of reticulated water; and b) A minimum of 50% of water is recycled.	A permanent bay car wash must not operate unless: a) the standard cycle uses 50 litres or less of reticulated water; b) a minimum of 50% of water is recycled; and	A permanent bay car wash must not operate unless using an alternative water source.

Appendix K (cont'd): TCC Water Restriction Policy

	Level 1	Level 2	Level 3	Level 4	Level 5
				c) a detailed water conservation plan has been approved by Council	
3.3 Mobile Car Washing	Permitted	Permitted	Bucket filled directly from a tap. Rinsed with water from a hose fitted with a trigger nozzle.	Bucket filled directly from a tap. Rinsed with water from a bucket.	No washing unless it operates using an alternative water source.
3.4 Motor Vehicle Dealers/Detailers	Permitted	Permitted	Bucket filled directly from a tap. Rinsed with water from a hose fitted with a trigger nozzle or approved vehicle washing system.	Bucket filled directly from a tap. Rinsed with water from a bucket or approved vehicle washing system.	Water must not be used to clean vehicles except to clean windscreens, windows and mirrors and then only using water from a bucket filled directly from a tap.
3.5 Trucks/trailers	Water must not be used except by means of a hand held hose fitted with a trigger device. Washings of trucks and trailers to comply with EPA requirements.	Water must not be used except by means of a hand held hose fitted with a trigger device. Washings of Trucks and trailers to comply with EPA requirements.	Water must not be used except by means of a hand held hose fitted with a trigger device. Washings of trucks and trailers to comply with EPA requirements.	Water must not be used except by means of a hand held hose fitted with a trigger device but only if such cleaning is necessary to meet public health and safety requirements. Washings of trucks and trailers to comply with EPA requirements.	Water must not be used except by means of a hand held hose fitted with a trigger device but only if such cleaning is necessary to meet public health and safety requirements. Washings of trucks and trailers to comply with EPA requirements.
4. WASHING OF BUILDINGS					