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DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF OPTIONS ANALYSIS

LUKANJI REGIONAL WATER SUPPLY FEASIBILITY STUDY

APPENDIX 6 : POTENTIAL AUGMENTATION SCHEMES

FINAL

NINHAM SHAND CONSULTING SERVICES

January 2006

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

DIRECTORATE OF OPTIONS ANALYSIS

LUKANJI REGIONAL WATER SUPPLY FEASIBILITY STUDY

APPENDIX 6

POTENTIAL AUGMENTATION SCHEMES

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January 2006

Title	:	**Appendix 6 : Potential Augmentation Schemes**
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LUKANJI REGIONAL WATER SUPPLY FEASIBILITY STUDY

POTENTIAL AUGMENTATION SCHEMES

EXECUTIVE SUMMARY

1. INTRODUCTION

The Lukanji Regional Water Feasibility Supply Study, commissioned by the Department of Water Affairs and Forestry (DWAF), commenced in March 2003. The main aim of the study is to review the findings of earlier studies and, taking cognisance of new developments and priorities that have been identified in the study area, to make a firm recommendation on the next augmentation scheme to be developed for the supply of water to the urban complexes of Queenstown and Sada following the implementation of a suitable water demand management programme. In addition, proposed operating rules will be identified for the existing water supply schemes and the augmentation scheme to provide for the ecological component of the Reserve and the equitable distribution of water between rural domestic and urban water supplies and irrigators.

In a previous study, the Queenstown Regional Water Supply Feasibility Study (QRWSFS) (DWAF, 1997), several alternative phased schemes were identified to meet the predicted water requirements of Queenstown and Sada/Whittlesea to the year 2045. The future water requirements were projected to 2045 from recorded water use to 1995, and the schemes were compared on the basis of their calculated Net Present Values (NPVs). The scheme with the lowest NPV was found to be one for which the proposed first phase was the construction of a pipeline from Xonxa Dam to Queenstown.

The actual growth in water requirements since 1995 has been significantly lower than predicted and, in addition, the unutilised Oxkraal Dam has become available to augment the supply to existing users. In view of this, it was not certain that a scheme that would entail the construction of the Xonxa Pipeline as its first phase would still be the most advantageous. Consequently, a number of alternative schemes were again investigated with the results presented in this report.

The current study includes the determination of environmental flow requirements, and updating predictions of irrigation and urban water requirements. The results of these investigations have been used to update the previous estimates of the quantities of water available from surface water resources for the supply to Queenstown.

Thus, the analysis repeats the calculations that were carried out for the QRWSFS with :

- estimated future water requirements adjusted in accordance with more recent information;
- sizes of pipelines and pump stations adjusted to suit the amended water requirements;

- pumping hours adjusted accordingly;
- the timing of the implementation of the various components of the schemes adjusted to suit the revised predictions of water requirements, and
- cost estimates updated to 2003.

Factors such as the likely impacts of the implementation of the Reserve on the yields of dams, and expected future irrigation water requirements, have been taken into account in determining the quantities of water available from the various sources.

Since the QRWSFS was completed, new information on groundwater potential in the area has shown that large volumes of groundwater could be abstracted on a sustainable basis. Consequently, the augmentation of the existing surface water supplies by means of groundwater abstraction is also considered in this report.

2. THE EXISTING URBAN WATER SUPPLY SITUATION

The existing urban water supply situation may be summarised as follows :

- The urban water requirements in the areas supplied by the existing schemes were 11,7 Mm^3/a in 2005 and are expected to increase to 13,5 Mm^3/a by 2020 and 15,5 Mm^3/a by 2045.

- The capacity of the existing raw water supplies to these schemes is 9,7 Mm^3/a at 1:50 year assurance, of which 7,5 Mm^3/a is provided from Waterdown Dam, 0,9 Mm^3/a from Bonkolo Dam and 1,3 Mm^3/a from boreholes at Ilinge.

- Because the water requirements exceed the available 1:50 year assured yields of the water sources, water is currently provided at a low assurance of supply. This is not a desirable situation and an augmentation scheme is urgently required.

- With the availability of water from Oxkraal Dam to provide some of the water for irrigation previously provided from Waterdown Dam, there is currently (2005) an additional 3,7 Mm^3/a of water available from Waterdown Dam if it is assumed that the allocation of water to irrigation will not be increased in the future or, alternatively, that additional irrigation water will be supplied, but the Reserve will not be implemented in the near future. However, the quantity is insufficient to meet the expected increase in the requirements of Queenstown to the year 2045, and a supplementary source would be required to do so. Also, even though the additional water is available in Waterdown Dam, it is not possible to supply it through the existing pipeline arrangement.

- There would be some scope for boosting the capacity of the existing Waterdown to Queenstown pipeline at relatively low cost, thereby postponing the date when an additional source of raw water will be required, if the currently unutilised 3,7 Mm^3/a of yield available from Waterdown Dam could be allocated to urban supplies. However, it appears from discussions held with the Department of Agriculture and the Chris Hani District Municipality that the water will be required in the near future for irrigation.

- There is also uncertainty as to whether the existing groundwater supply to Ilinge will continue in use or be shut down when a planned supply from the Queenstown Water Treatment Works becomes available to Ilinge and the Macibini Villages. Therefore, for purposes of comparing possible augmentation schemes, it was assumed that the groundwater supply would be abandoned.

3. POTENTIAL AUGMENTATION SCHEMES

Conceptual designs of a number of alternative schemes for augmenting the water supply to Queenstown were prepared, capital and operating costs were estimated for each scheme, and the long-term costs of the schemes were compared on the basis of the costs, expressed as unit reference values, of the water that they could provide.

It was shown by this analysis that the existing pipeline between Waterdown Dam and Queenstown is of high economic value. As it is reported to still be in good condition, it is likely to remain in service for the foreseeable future, even though it is now forty-five years old. The analysis also showed that augmentation of the Queenstown water supply from a new dam or diversion weir to be constructed on the Black Kei River would be considerably more costly than augmentation from the existing Xonxa Dam, or from the existing Waterdown Dam, if sufficient water could be made available from the latter.

The investigations carried out for this study have shown that there is sufficient unallocated water available from Xonxa Dam to meet the expected increase in the water requirements of Queenstown to beyond the year 2045.

The financial comparison of possible augmentation schemes showed that it would not be economical to supplement the raw water supply by raising Waterdown Dam. However, a pre-feasibility level desktop assessment of groundwater potential in the area has shown good prospects for the development of wellfields in the vicinity of Sada. Therefore, the possibility was considered of increasing the quantity of water that could be supplied to Queenstown from Waterdown Dam by developing a groundwater supply for Sada, and thereby making available for the Queenstown supply the water currently supplied to Sada from Waterdown Dam.

It was concluded from the financial comparison of schemes that :

- it would be more economical to construct a pipeline between Xonxa Dam and Queenstown sized initially to convey the full quantity of water required in the year 2045 than to construct two smaller pipelines in phases;

- in terms of the unit reference values for water supplied over the period from 2005 to 2045, there would be little difference between augmentation from Waterdown Dam, with a new groundwater supply included, and augmentation entirely from Xonxa Dam;
- augmentation partially from Waterdown Dam, (without groundwater supply but with a second pipeline) and partially from Xonxa Dam would cost about 30% more, in terms of unit reference values, than augmentation exclusively from either of the sources.

In view of the above, it is necessary to make a choice between augmentation from Waterdown Dam and augmentation from Xonxa Dam. The choice is made easier by certain advantages which are apparent in the Xonxa Dam option, namely:

(i) The raw water source already exists, whereas the groundwater source for the Waterdown Dam option has still to be proved in the field, and the cost of developing it may be significantly higher than estimated.

(ii) The initial capital cost of the Xonxa Pipeline, estimated to be R68 million, is considerably lower than the estimated R90 million for the Waterdown Pipeline, and it would, therefore, be easier to finance. (The disadvantage is that the Xonxa Pipeline pumping costs would be higher than those from Waterdown Dam).

(iii) A supply from Xonxa Dam would be from a completely separate source, which would reduce the risk of complete disruption of the supply in the event of a natural disaster.

(iv) There is unutilised yield available from Xonxa Dam, whereas the additional water that would be used from Waterdown Dam is very likely to be required in the near future for use for irrigation by small scale farmers.

(v) Xonxa Dam lies in a region with different hydrological characteristics to the region in which Waterdown Dam is situated. Droughts in the two regions do not have a high correlation, a factor which has benefits for the operation of the system.

For the above reasons, augmentation from Xonxa Dam is preferred to augmentation from Waterdown Dam.

4. RECOMMENDATIONS

The following recommendations are made :

- The water supply to Queenstown should be augmented by means of a pipeline between Xonxa Dam and Queenstown.
- The pipeline should be sized to deliver about 6,4 Mm^3/a of raw water to Queenstown to meet expected requirements to the year 2045.

- The advantages of using Bonkolo Dam as balancing storage and the future status of the Ilinge groundwater supply should be taken into account in the detailed design of the pipeline.

LUKANJI REGIONAL WATER SUPPLY FEASIBILITY STUDY

POTENTIAL AUGMENTATION SCHEMES

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ABBREVIATIONS

DWAF	Department of Water Affairs and Forestry
QRWSFS	Queenstown Regional Water Supply Feasibility Study
NPV	Net Present Value
m^3	cubic metres
Mm^3/a	Million cubic metres per year
p.a.	per annum
km	kilometre
WASSA	Water and Sanitation Services South Africa
ha	hectare

LUKANJI REGIONAL WATER SUPPLY FEASIBILITY STUDY

POTENTIAL AUGMENTATION SCHEMES

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Factors such as the likely impacts of the implementation of the Reserve on the yields of dams, and expected future irrigation water requirements, have been taken into account in determining the quantities of water available from the various sources.

Since the QRWSFS was completed, new information on groundwater potential in the area has shown that large volumes of groundwater could be abstracted on a sustainable basis. Consequently, the augmentation of the existing surface water supplies by means of groundwater abstraction is also considered in this report.

2. WATER REQUIREMENTS

For the purpose of this investigation, the following water requirement projections for Queenstown and Sada, as well as rural villages that are also likely to be supplied from the scheme, were used :

2.1 QUEENSTOWN

The population growth rate that was assumed for Queenstown in the QRWSFS was 3,5% p.a. The more recent demographic studies for the development of the National Water Resource Strategy have estimated a growth rate for Queenstown as 1,61% p.a. from 1995 to 2005, followed by a growth of 0,87% p.a. from 2005 to 2015 and subsequently a growth rate of 0,61% from 2015 to 2025. The metered raw water-use in 2002 was 7,3 Mm^3/a. At the end of 2002, a large low cost housing scheme was completed which is estimated by the Town Engineer of Queenstown to have increased water requirements by 0,3 Mm^3/a to 7,6 Mm^3/a. Using the estimates of future population growth rates given above, and assuming the growth rate between 2025 and 2045 to remain at 0,61% p.a., gives a water requirement in 2045 of 10,3 Mm^3/a.

2.2 SADA

The QRWSFS predicted that the water requirements of Sada would grow at 3,36% from 2,03 Mm^3/a in 1995 to 2,42 Mm^3/a in 2000. Thereafter, the growth rate was predicted to decrease to 2,73% p.a., to give a water requirement in 2005 of 2,77 Mm^3/a. It appears that the actual water use in 2003 was 2,4 Mm^3/a. This value was obtained from the Town Engineer of Queenstown. A rough check was performed by subtracting the quantity of water supplied from Waterdown Dam to Queenstown from the total quantity released from the dam into the pipelines to Sada and Queenstown between October 2002 and September 2003. This showed a water use of 2,01 Mm^3 in that twelve month period, which is in reasonable agreement with the value of 2,4 Mm^3 assumed for the 2003 calendar year.

The demographic studies commissioned by DWAF for the development of the National Water Resource Strategy (DWAF, 2000) predicted that the population of Sada would grow at 0,3% p.a. to 2020, and would remain virtually static thereafter. For the purposes of this analysis of water augmentation schemes, it has been assumed that the future increases in water requirements will follow these predicted population growth rates. On this basis, water requirements will increase to 2,52 Mm^3/a by 2020, and then remain almost static. However, the village of Zulukama and other rural villages in the vicinity of Sada are likely to be connected to the Sada water supply in the future. Therefore, in consultation with the Town Engineer of Queenstown, a water requirement of 2,40 Mm^3/a in 2003, increasing to 2,50 Mm^3/a by 2020, and 3,0 Mm^3/a by 2045, was assumed.

2.3 ILINGE

The small town of Ilinge, situated some 8 km south-east of Queenstown, had a water requirement of 1,38 Mm^3/a in 2002, according to the Town Engineer of Queenstown. This is expected to increase to 1,44 Mm^3/a by 2005, and remain static thereafter.

2.4 RURAL VILLAGES

Estimates of the future water requirements of rural villages in the area vary significantly.

The demographic study conducted for the National Water Resource Strategy indicates rural population growth rates of 0,37% p.a. up to 2005, followed by a negative growth rate of 0,4% p.a. from 2005 to 2015 and a negative growth of 0,85% p.a. from 2015 to 2025. If these rates are used for projecting the water requirements of the rural villages (Macibini Villages) that are situated near the Queenstown end of the proposed Xonxa Pipeline route, a water quantity of 0,74 Mm^3/a in 2002 decreasing to 0,55 Mm^3/a in 2025 is obtained. Based on recent population figures, a population growth rate of 1,5% p.a. was used for the latest study of the Xonxa Dam Transfer Scheme (Stewart Scott, 2003), and the water requirements of the Macibini Villages were predicted to be about 1,49 Mm^3/a in 2045, based on 1997 water requirements of 0,73 Mm^3/a. For purposes of this study, it has been assumed that the requirements will grow to 0,76 Mm^3/a by 2005 and then remain static.

The QRWSFS predicted that the rural water requirements that could be supplied from the Xonxa pipeline along its route would grow from a negligible quantity in 1990 to 1,22 Mm^3/a in 2045. Uhlmann, Withaus and Prins (1996) forecast a rural demand of about 0,8 Mm^3/a in 2015, which would increase to 3,5 Mm^3/a in 2045.

The water requirements of the Macibini Villages have been included in the design flow rates for all the pipelines considered (on the assumption that the villages will be supplied from the Queenstown Water Treatment Works by a separate potable water pipeline irrespective of the raw water scheme implemented). The requirements of the other villages in the vicinity of the Xonxa pipeline route have not been included in the analysis because they would not be supplied by any of the other schemes with which the Xonxa pipeline is compared. If it is decided to proceed with the Xonxa pipeline it may be necessary to provide for the additional rural requirements in the design.

2.5 TOTAL URBAN AND RURAL DOMESTIC REQUIREMENTS

The total projected potable water requirements from the scheme are summarised in Table 2.1. It can be seen that the requirements are expected to increase from 12,46 Mm^3/a in 2005 to 15,5 Mm^3/a in 2045.

TABLE 2.1 PROJECTED WATER REQUIREMENTS FOR QUEENSTOWN AND RURAL VILLAGES

AREA	WATER REQUIREMENTS (Mm³/a)					
	1990	1995	2003	2005	2020	2045
Queenstown complex	5,58	7,60	7,60	7,85	8,80	10,30
Sada and rural villages	1,23	1,40	2,40	2,41	2,50	3,00
Ilinge and Macibini villages	0,54	0,64	2,18	2,20	2,20	2,20
Totals	**7,35**	**9,64**	**12,18**	**12,46**	**13,50**	**15,5**

2.6 POTENTIAL FOR WATER CONSERVATION AND DEMAND MANAGEMENT

It can be seen from Table 2.1 that the growth in the water requirements of the Queenstown Complex did not increase between 1995 and 2003. In fact, water use decreased in the intervening years to a low of 5,96 Mm^3/a in 2000, but has increased again as low cost housing schemes have been implemented. The decrease between 1995 and 2000 is attributed to the effects of water demand management.

According to figures supplied by WASSA, the company that operates the Queenstown potable water supply scheme, water losses are about 22% of raw water requirements. Most of the losses occur in the potable water distribution system.

The above statistics suggest that there is little scope for reducing water consumption further by water demand management, but that significant savings could be made by reducing losses. However, this is likely to be a long-term process because of the difficulties of repairing old water reticulation systems. Therefore, any savings that could be achieved have not been allowed for in the estimates of future water requirements shown in Table 2.1.

2.7 IRRIGATION

Estimates of present and future irrigation requirements have been made as shown in Table 2.2 in consultation with officials of the Provincial Department of Agriculture. There is considerable uncertainty about the extent to which additional irrigated land will be developed in the future, but the estimates shown in Table 2.2 are based on the best available information.

TABLE 2.2 IRRIGATION WATER REQUIREMENTS

SCHEME/ RIVERS	DAM	LOCATION	IRRIGATION IN 2002		POTENTIAL MAXIMUM FUTURE IRRIGATION	
			IRRIGATED AREA (ha)	WATER REQUIRE-MENTS (Mm^3/a)	IRRIGATED AREA (ha)	WATER REQUIRE-MENTS (Mm^3/a)
Klipplaat River Irrigation Scheme	Waterdown(1)	Waterdown to Oxkraal	206	1.57	600	4.58
		Oxkraal to Black Kei	315	2.40	315	2.40
		Black Kei to Klaas Smits	192	1.47	192	1.47
		Klaas Smits to White Kei	817	6.23	817	6.23
		Total	1530	11.67	1924	14.68
Oxkraal Irrigation Scheme	Oxkraal (1)	Downstream of Oxkraal Dam	0	0	541	4.13
	Shiloh (1)	Downstream of Shiloh Dam	0	0	25	0.19
		Total	0	0	566	4.32
Xonxa Irrigation Scheme	Xonxa (2)	Downstream of Xonxa Dam	60	6.75	1000	11.25
Zweledinga Irrigation Scheme	Bushmanskrantz	Downstream of Bushmans-krantz Dam	0	0	259(3)	1,50(3)

(1) Water requirement calculated as 6 100 $m^3/ha/a$ + 25% conveyance losses. (The allocation of 6 100 $m^3/ha/a$ is lower than the actual field edge requirements of the crops grown at present which has been calculated to be 7 300 $m^3/ha/a$ (DWAF, 1993)).
(2) Water requirement calculated as 9 000 $m^3/ha/a$ + 25% conveyance losses.
(3) This is a previously developed scheme that has fallen into disuse. There are no known plans to rejuvenate it, but this could change at any time in the future.

Some explanation of the arrangements for irrigation follows :

Waterdown Dam supplies water for the Klipplaat Irrigation scheme. Water is released from the dam into the river channel to supply a scheduled irrigated area of 1 924 ha along the Klipplaat River to its confluence with the Black Kei, and along the Black Kei to its confluence with the White Kei.

It appears that, at present, the 394 ha Shiloh Irrigation Scheme portion of the scheduled area of 600 ha of land between Waterdown Dam and the Oxkraal River confluence with the Klipplaat River has either not been developed, or has fallen into disuse. The currently irrigated area is assumed to be 1 530 ha, but refurbishment of the Shiloh Irrigation Scheme is expected to result in due course in the full scheduled area of 1 924 ha being irrigated.

Water allocations are 6 100 $m^3/ha/a$, and conveyance losses of 25% of the allocation need to be added. On this basis, the current irrigation requirement from Waterdown Dam is calculated to be 11,67 Mm^3/a, and the future requirement 14,68 Mm^3/a. The distribution of these requirements between Waterdown Dam and the Black Kei River confluence with the White Kei River is shown in Table 2.2.

Oxkraal Dam was built to supply water for irrigation along the Oxkraal River between the dam and the confluence of the Oxkraal and Klipplaat Rivers. The land has not been developed yet, but some 566 ha of land might be developed at some stage in the future (25 ha of this land would be supplied with water from the small Shiloh Dam). The development of this land is uncertain at present. It will depend on a number of factors which include the need to promote irrigation by resource poor farmers, the extent of over-allocation of water from Waterdown Dam, and the quantity of water required for the Reserve. One of the purposes of this study is to make a recommendation on appropriate use of the water from Oxkraal Dam. Therefore, while no water from these dams is used at present on the land for which it was intended, the future requirements, calculated on the same basis as described above for Waterdown Dam, could be anywhere between nothing and 4,32 Mm^3/a. (In recent years, Oxkraal Dam has been used to supply water to irrigated land scheduled under Waterdown Dam.)

In summary, therefore, the combined irrigation requirements from Waterdown, Oxkraal and Shiloh Dams are 11,67 Mm^3/a at present, and might increase to 19,00 Mm^3/a in the future.

Xonxa Dam was built in 1972 to provide water for the irrigation of some 4 900 ha of land along the White Kei River. To date, only 1 643 ha of land have been developed and much of this land has fallen into disuse, with the result that only about 60 ha was irrigated in 1995 (DWAF, 2002). It was suggested in the report on the QRWSFS that, because of the unsuitability of much of the soil for irrigation, it is unlikely that the irrigated area will ever increase to more than 1 000 ha. Therefore, on the basis of a current irrigated area of 60 ha, a maximum future irrigated area of 1 000 ha, a field edge water requirement of 9 000 $m^3/ha/a$, and 25% conveyance losses, present and expected future irrigation requirements from the dam have been estimated to be, respectively, 0,68 Mm^3/a and 11,25 Mm^3/a.

2.8 ECOLOGICAL FLOW REQUIREMENTS

As part of this study, the ecological flow requirements of the relevant rivers were determined at selected points. The determinations were made in accordance with the procedures currently prescribed by DWAF for achieving results at an intermediate level of confidence.

The impacts on the 1:50 year yields of the dams that would result from implementing ecological releases that would maintain the rivers in their present ecological states were estimated to be :

Waterdown	- 3,7 Mm^3/a
Oxkraal	0
Xonxa	- 3,1 Mm^3/a

The above are based on the assumptions that :

1. the full yield of Oxkraal Dam would be used to provide irrigation requirements, with Waterdown Dam providing all the ecological flow requirements (within the limits of outlet capacity) of the Klipplaat River and the Black Kei River downstream of the Klipplaat confluence; and
2. The provision of ecological flow requirements in the White Kei River would be split between Xonxa (3,1 Mm^3/a) and Lubisi Dams (1,2 Mm^3/a) in proportion to their mean annual runoffs.

3. EXISTING WATER SOURCES

Several existing dams are either used at present to supply the water requirements of Queenstown and surrounding areas or could be used in the future. Descriptions of these follow :

3.1 WATERDOWN DAM

Waterdown Dam (36,1 Mm^3 capacity) is situated on the Klipplaat River some 45 km south of Queenstown and supplies water to the urban areas of Queenstown and Sada/Whittlesea and to the Klipplaat Irrigation Scheme. The 1:50 year yield of Waterdown Dam is 20,3 Mm^3/a and the 1:10 year yield is 24,5 Mm^3/a (see Appendix 4 for details of the yield analyses).

Irrigation releases from Waterdown Dam have decreased from about 14 Mm^3/a in 1995 to only 0,9 Mm^3/a in 2002 (DWAF). This has occurred partially because the Shiloh Irrigation Scheme, with an original allocation of 2,47 Mm^3/a has fallen into disuse and partially because about 5 Mm^3/a of water previously supplied from Waterdown Dam has been supplied from Oxkraal Dam since 1999. However, this does not account fully for the decrease in irrigation releases from Waterdown Dam. It is possible that there has been sufficient water in the Klipplaat and Black Kei Rivers in recent years to satisfy the requirements of irrigators, with the result that relatively small quantities of water have been required from the dams. However, there is little doubt that the full allocation of 14,3 Mm^3/a will be required from the dams in future dry years.

The Queenstown Water Supply Scheme provides water for domestic and industrial use to Queenstown and eZibeleni. The allocation to Queenstown from the Waterdown Dam for this purpose is 8,25 Mm^3/a. Water is conveyed from Waterdown Dam via a pipeline to the Berry Reservoir in Queenstown. The water is then treated and pumped to various reservoirs.

The Sada-Whittlesea Scheme utilises water allocated from the Waterdown Dam to supply the towns of Sada and Whittlesea. The allocation from Waterdown Dam is 4,2 Mm^3/a. The water supply is drawn from the main Waterdown-Queenstown pipeline via a metered offtake. It is then conveyed via a gravity pipeline to the Sada Water Treatment Works and pumped to various reservoirs in the area.

Allocations of water from Waterdown Dam total 27,48 Mm^3/a, which is well in excess of the 1:50 year yield of 20,3 Mm^3/a, or even the 1:10 year yield of 24,5 Mm^3/a. However, it appears that, as discussed in Section 3.5 below, it may be feasible to supplement supplies of irrigation water from Waterdown Dam with releases from Oxkraal Dam.

3.2 BONKOLO DAM

Bonkolo Dam has a capacity of 6,95 Mm^3, a 1:50 year yield of 0,9 Mm^3/a and a 1:10 year yield of 1,2 Mm^3/a (see Appendix 4 for details of the yield analysis). It is situated on the Bonkolo River north of Queenstown and only supplies water to Queenstown.

3.3 BUSHMANSKRANTZ DAM

Bushmanskrantz Dam is situated in the upper reaches of the Oxkraal River. It has a capacity of 4,7 Mm^3 and a yield of approximately 2,2 Mm^3/a at 1:50 year assurance. Bushmanskrantz Dam was constructed as part of the Zweledinga Irrigation Scheme to supply water by means of a pipeline to small scale farmers along the Oxkraal River. Water is also supplied to the villages of Yonda and Mbekweni, each of which has its own small treatment works. The requirements of the villages total about 0,04 Mm^3/a.

According to DWAF records, no releases of water for irrigation have been made from Bushmanskrantz Dam since 1995.

3.4 OXKRAAL DAM

Oxkraal Dam has a capacity of 13,8 Mm^3 and is situated on the Oxkraal River downstream of Bushmanskrantz Dam and immediately west of Sada/Whittlesea. It was built to supply the Oxkraal Irrigation Scheme, which was planned to comprise 60 ha of lands on the banks of the dam and 481 ha downstream, but has never been implemented. Since 1999, between 4 and 5,25 Mm^3/a of water has been released from the Oxkraal Dam for irrigation purposes along the Klipplaat River. The yield of Oxkraal Dam, as determined in this study, is 4,8 Mm^3/a at 1:50 year assurance. If only the requirements of the Yonda and Mbekweni villages were abstracted from Bushmanskrantz Dam and the remainder of its yield were allowed to run down the channel of the Oxkraal River into Oxkraal Dam, the yield obtainable from the latter would increase to 7,0 Mm^3/a at 1:50 year assurance and 8.6 Mm^3/a at 1:10 year assurance.

3.5 SHILOH DAM

Shiloh Dam was constructed as part of the Oxkraal Irrigation Scheme and was intended to irrigate 25 ha of land immediately downstream, but the land has not been developed to date and the dam has not been used for any other purpose. Shiloh Dam has a firm yield of 0,3 Mm^3/a (QRWSFS). Shiloh Dam, being so small, was not included in the stochastic analysis carried out in the current study. However, by applying to the firm yield of Shiloh Dam, the ratios between the yields at different assurances determined for Oxkraal Dam, the 1:50 year and 1:10 year yields of Shiloh Dam were estimated to be 0,3 Mm^3/a and 0,4 Mm^3/a, respectively.

3.6 COMBINED USE OF WATERDOWN, BUSHMANSKRANTZ, OXKRAAL AND SHILOH DAMS

The combined 1:50 year yields of Waterdown, Bushmanskrantz, Oxkraal and Shiloh Dams total 27,6 Mm^3/a (20,3 Mm^3/a + 7,0 Mm^3/a + 0,3 Mm^3/a).

The present water allocations are the existing urban allocation of 12,65 Mm^3/a, which is assumed to be supplied at 1 in 50 year assurance, and the irrigation allocation of 14,83 Mm^3/a, which can probably reasonably be supplied at an assurance of 1 in 10 years. These allocations are both from Waterdown Dam and do not take account of the irrigated lands that Bushmanskrantz, Oxkraal and Shiloh Dams were constructed to supply with water. As explained above, these lands have either fallen into disuse or have never been developed for irrigation.

It can be seen from Table 2.1 that the estimated water requirement of Queenstown in 2005 is 7,85 Mm^3/a, of which Bonkolo Dam can supply 0,9 Mm^3/a at 1:50 year assurance. Therefore, the requirement from Waterdown Dam is 6,95 Mm^3/a for Queenstown. In addition, Sada requires 2,41 Mm^3/a. Thus, the total potential urban and rural village requirements from Waterdown Dam in 2005 are 9,36 Mm^3/a. However, for the reasons given in Section 4, the existing pipeline to Queenstown can deliver a maximum of 5 Mm^3/a, if the requirements of Sada are supplied at the same time. Therefore, the actual total urban use from Waterdown Dam in 2005 is likely to be 7,41 Mm^3/a (5 Mm^3/a for Queenstown and 2,41 Mm^3/a for Sada).

It is understood that refurbishment of the Shiloh Irrigation Scheme is currently underway and, if it is assumed that this will be completed in 2005, but that no development of the Oxkraal Irrigation Scheme will have occurred, the total irrigation requirement in that year will, from Table 2.2, be 14,68 Mm^3/a. Thus, it seems likely that the urban water requirements in 2005 will be less than the present allocation, while the irrigation requirement will be roughly equal to the allocation.

The 1 in 50 year yield of Waterdown Dam is about 83% of the 1 in 10 year yield. Therefore, it can be assumed that the equivalent irrigation water requirement at 1 in 50 year assurance is roughly 83% of the 1 in 10 year 2005 requirement of 14,68 Mm^3/a, i.e. 12,18 Mm^3/a at 1 in 50 year assurance. On this basis, the total equivalent requirement in 2005 from the Waterdown, Bushmanskrantz, Oxkraal and Shiloh Dams at 1 in 50 year assurance is 19,59 Mm^3/a. This is made up as follows :

Urban requirement at 1:50 year assurance	7,41 Mm^3/a
Equivalent irrigation requirements at 1:50 year assurance	12,18 Mm^3/a
Total equivalent requirement at 1:50 year assurance	19,59 Mm^3/a

This is 8,01 Mm^3/a less than the assumed combined 1 in 50 year yield of the dams of 27,6 Mm^3/a. A further consideration is that ecological flow requirements, which have not been released from the dams in the past, may be required in the future. The ecological flow requirements have been determined in the current study. It seems likely that the release of ecological flow requirements, when implemented, will reduce the yield of the dams available for other purposes by up to 3,7 Mm^3/a. If this were taken into account, there would be a surplus of 4,31 Mm^3/a of yield at 1:50 year assurance relative to assumed requirements in 2005, calculated as follows :

Combined 1:50 year yield of dams	27,6 Mm^3/a
Less 1:50 year equivalent irrigation requirements in 2005	
Klipplaat Scheme potential maximum = 14,68 Mm^3/a x 0,83	
(factor to convert from 1:10 year to 1:50 year)	12,18 Mm^3/a
Water available for other supplies	15,42 Mm^3/a
Less Sada and villages (2005)	2,41 Mm^3/a
Less present Queenstown usage	5,00 Mm^3/a
Unused in 2005	8,01 Mm^3/a
Less provision for ecological Reserve	3,70 Mm^3/a
Balance	4,31 Mm^3/a

It is of interest, with regard to future development, to consider the availability of water from the dams for the full potential irrigated areas shown in Table 2.2. If the areas below Oxkraal and Shiloh were developed, the irrigation water requirements at 1:10 year assurance from Waterdown, Bushmanskrantz, Oxkraal and Shiloh Dams combined would increase by 4,32 Mm^3/a from 14,68 Mm^3/a in 2005 to 19,00 Mm^3/a. If provision were made for both this additional irrigation requirement and the predicted increase of 0,59 Mm^3/a in the water requirements of Sada, the surplus in yield of 4,31 Mm^3/a in 2005 would reduce to 0,13 Mm^3/a, calculated as follows :

Surplus 1:50 year yield in 2005	4,31 Mm^3/a
Less future requirements of Sada	0,59 Mm^3/a
Less 1:50 year equivalent future irrigation requirements 4,32 x 0,83	3,59 Mm^3/a
Balance	0,13 Mm^3/a

If, in addition, the Zwelidinga Irrigation Scheme below Bushmanskrantz Dam were rejuvenated, an additional 1:50 year equivalent irrigation quantity of 1,50 Mm^3 x 0,83 = 1,25 Mm^3/a would be required. In that case there would be a shortfall in yield of 1,02 Mm^3/a.

Alternatively, if it were decided to fix the irrigation allocation from the dams at the 2005 level, an additional 4,31 - 0,59 = 3,72 Mm^3/a could be made available to Queenstown after allowing for the future requirements of Sada.

3.7 XONXA DAM

Xonxa Dam has a capacity of 112,4 Mm^3. The 1 in 50 year yield of Xonxa Dam was determined in this study to be 23,0 Mm^3/a and the 1 in 10 year yield 29,6 Mm^3/a. Therefore, after allowing for the probable maximum future irrigation requirement of 11,25 Mm^3/a (see Table 2.2) at 1 in 10 year assurance, or 8,77 Mm^3/a at 1 in 50 year assurance, and the impact on yield of the ecological Reserve requirement of 3,1 Mm^3/a, there would still be 11,1 Mm^3/a available for other uses at an assurance of 1 in 50 years. This is calculated as follows :

1:50 year yield of Xonxa Dam	23,0 Mm^3/a
Less probable 1:50 year maximum future irrigation requirement	
11,25 Mm^3/a x 0,78	8,8 Mm^3/a
Less provision for ecological Reserve	3,1 Mm^3/a
Available for other supplies	11,1 Mm^3/a

4. THE EXISTING URBAN WATER SUPPLY SCHEME

Queenstown receives raw water from Bonkolo Dam and from Waterdown Dam, while Sada is supplied from Waterdown Dam only.

Water from Bonkolo Dam is supplied through a gravity pipeline to Berry Dam, a small balancing reservoir of about 0,3 Mm^3 capacity, and from there to the Queenstown Water Treatment Works. The pipeline from Bonkolo Dam consists of a short length of 450 mm diameter steel piping followed by 500 mm diameter fibre cement piping. The capacity of the pipeline is about 0,25 m^3/s (21,6 Mℓ/d) when Bonkolo Dam is at its minimum operating level (QRWSFS).

The water treatment works has a capacity of 42 Mℓ/day.

Water from Waterdown Dam is supplied to the Berry Dam in Queenstown through a 46 km long, 450 mm diameter, steel pipeline constructed in 1960. The pipe has a wall thickness of 6 mm. The pipeline was originally designed to operate under gravity only, but its capacity was later boosted by a pump station some 7 km from Queenstown.

In about 1983, in order to supply the newly established Sada resettlement area and to meet the growing demand of Queenstown, a second pipeline was constructed along the first 15 km of the route from Waterdown Dam. This is a ductile iron pipeline of diameter successively 600 mm, 500 mm and 450 mm. A 400 mm diameter offtake to Sada Water Treatment Works was provided 7 km from Waterdown Dam, at the end of the 600 mm diameter section of pipeline. At about the same time, a new booster pump station was constructed on the original pipeline 16 km from Queenstown, and the original pump station was taken out of use.

According to the August 1981 report by Stewart, Sviridov & Oliver, the Waterdown Dam to Queenstown pipeline was designed to deliver between 11,3 Mℓ/day and 9,5 Mℓ/day to Queenstown under gravity, depending on the water level in Waterdown Dam. The new booster pump station, with variable speed motors, located at McEwan's Flats, some 23 km beyond the Sada branch, was installed to increase the delivery to between 25 Mℓ/day and 23 Mℓ/day, depending on the water level in Waterdown Dam.

The design provided for the supply of 23 Mℓ/day to Queenstown to be maintained, with Waterdown Dam at its lowest level, while providing an additional 17 Mℓ/day at the Sada offtake for delivery to the Sada Water Treatment Works.

Because of the relative levels, the full 17 Mℓ/day could not be supplied to the Sada Treatment Works by gravity. Therefore, a booster pump station was required on the branch pipeline to Sada (report by Anstey, Blignaut and Clogg, 1980). However, this was not constructed when the pipeline was laid in about 1983 because the water requirements at that time could be supplied by gravity alone.

The booster pump station has still (2005) not been constructed but the requirements of the Sada Water Treatment Works have increased to about 2,4 million m^3/annum, which is an average of approximately 6,5 Mℓ/day, with the seasonal peak daily demand being about 10 Mℓ/day.

Because the booster pump station has not been constructed, it is necessary to keep the pressure in the Waterdown Dam to Queenstown pipeline at the Sada offtake at a higher level than originally intended if sufficient water is to be supplied to Sada. This can only be done by limiting the delivery to Queenstown by operating the booster pumps at McEwan's Flats at less than their full capacity.

It is reported (Stewart Scott, January 2003) that, as a result of this situation, Queenstown can obtain a maximum of 13,7 Mℓ/day through the pipeline, instead of the minimum of 23 Mℓ/day for which it is designed. As the present requirement of Queenstown, excluding Ilinge and the Macibini Villages, is about 7,8 Mm^3/a, it is necessary to supply from Bonkolo Dam the difference of 2,8 Mm^3/a between the 5 Mm^3/a that can be obtained through the Waterdown Dam pipeline and the total requirement. The quantity of 2,8 Mm^3/a is well in excess of the 1 in 10 year yield of Bonkolo Dam and can be supplied only at very low assurance. The rainfall in the area has been good in recent years and sufficient water has been obtained from Bonkolo Dam, except in 2004, when water restrictions were imposed in Queenstown, even though sufficient water was available in Waterdown Dam. It is clear, therefore, that augmentation of the existing raw water supply scheme is urgently required.

Ilinge and the adjacent Macibini Villages are not connected to the Queenstown water supply at present, but are supplied from six boreholes with an estimated yield of 1,3 Mm^3/a (DWAF, 1993). The present water requirements are estimated to be 2,2 Mm^3/a, which suggests that the scheme requires augmentation. Borehole yields in the area are generally good, and it should, therefore, be feasible to augment the scheme by developing additional boreholes (DWAF, 1993). However, the scheme has proved difficult to manage and problems in operating it effectively have been experienced for many years. Consequently, the Chris Hani District Municipality would prefer to supply the area by means of a new pipeline from the Queenstown Water Treatment Works.

It is clear from the above description of the existing water supply to Queenstown that, in order to avoid severe water shortages, Ilinge should not be added to the Queenstown supply area before the raw water supply has been augmented. (It will probably also be necessary to increase the capacity of the water treatment works, but that is not within the scope of this study.).

5. AUGMENTATION OPTIONS

5.1 AVAILABLE YIELD FROM EXISTING RAW WATER SOURCES

The estimated current and future raw water requirements at the Queenstown Water Treatment Works are compared with the available yields from the present sources of raw water in Table 5.1. The available yields are :

- the combined yields of Waterdown, Bushmanskrantz, Oxkraal and Shiloh Dams of 27,6 Mm^3/a after allowing for the impact of the ecological Reserve (3,7 Mm^3/a) and subtracting the estimated future (2045) requirements of Sada of 3,0 Mm^3/a, the yield of the existing Waterdown Pipeline of 5 Mm^3/a, and the equivalent 1:50 year irrigation requirements in 2005 of 12,18 Mm^3/a, assuming that the full yields of Bushmanskrantz, Oxkraal and Shiloh Dams will be used to provide part of the allocations to irrigation from Waterdown Dam.

- the 1:50 year yield of Bonkolo Dam of 0,9 Mm^3/a.

It should be noted that, in practice, water could in the near future be allocated to both the Zweledinga and Oxkraal Irrigation Schemes, thereby bringing the total equivalent 1:50 year allocation to irrigation to 20,50 Mm^3/a x 0,83 = 17,02 Mm^3/a. The assumption of the present requirement of 12,18 Mm^3/a is made purely for purposes of comparing possible augmentation schemes.

It is similarly assumed that the existing supply of 1,3 Mm^3/a from the Ilinge boreholes will be discontinued, but, as discussed in Section 10.5, this might not be the case in practice.

TABLE 5.1 ESTIMATED URBAN WATER REQUIREMENTS AND YIELD AVAILABLE FROM EXISTING RAW WATER SOURCES

ITEM	YEAR		
	2005 (Mm^3/a)	2020 (Mm^3/a)	2045 (Mm^3/a)
Queenstown water requirements (including Ilinge and Macibini villages)	10,05	11,00	12,50
Less existing 1:50 year yield of Bonkolo Dam	0,90	0,90	0,90
Less yield of existing Waterdown Pipeline	5,00	5,00	5,00
Additional yield required	4,15	5,10	6,60
Potentially utilisable 1:50 year yield of Waterdown, Bushmanskrantz, Oxkraal and Shiloh Dams (after implementation of the Reserve)	3,72	3,72	3,72
Yield required from other sources	0,43	1,38	2,88

Table 5.1 shows that additional yield of 4,15 Mm^3/a is required in 2005, increasing to 6,6 Mm^3/a by 2045 if the maximum delivery through the Waterdown Pipeline is assumed to remain at 5,0 Mm^3/a. If it were decided that all of the combined yields of the three dams that is unused in 2005 should be used for the future requirements of Sada and Queenstown, and the conveyance capacity between Waterdown Dam and Queenstown were increased accordingly, additional water would still be required. The quantity would increase from 0,43 Mm^3/a in 2005 to 2,88 Mm^3/a in 2045.

5.2 POTENTIAL ADDITIONAL RAW WATER SOURCES

Potential sources of additional surface water are discussed in detail in the QRWSFS. The most favourable of these for the size of supply now envisaged are listed in Table 5.2 and described below, as are potential groundwater sources identified in the current study.

TABLE 5.2 POTENTIAL SOURCES OF ADDITIONAL YIELD

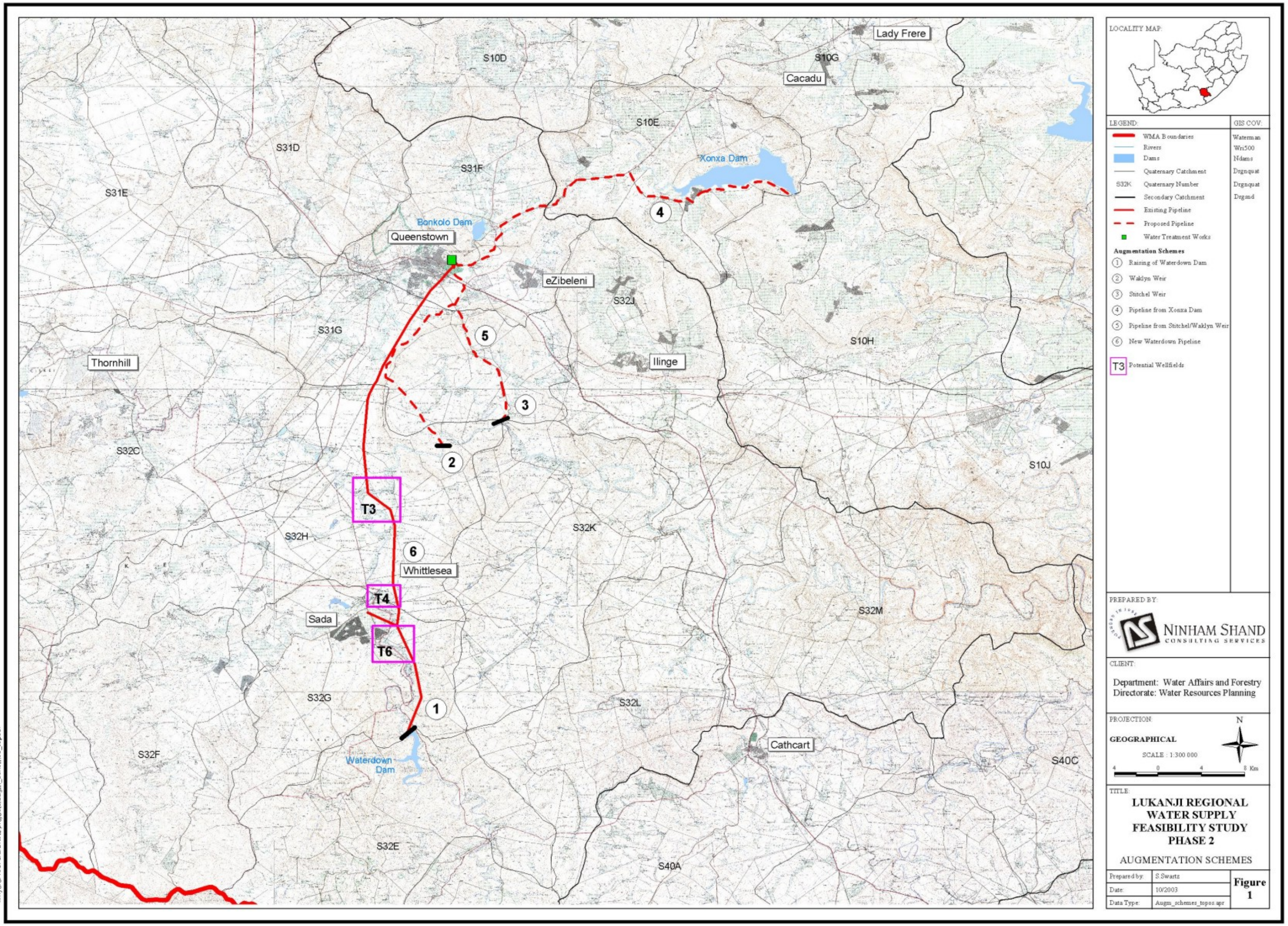
SOURCE	YIELD AT 1:50 YEAR ASSURANCE
Raising of Waterdown Dam	4,3 Mm^3/a
A weir on the Black Kei River at Waklyn	Up to 5,7 Mm^3/a
A weir on the Black Kei River at Stitchel	Up to 7 Mm^3/a
Xonxa Dam	11,1 Mm^3/a
Groundwater in the vicinity of Sada	Between 3 Mm^3/a and 6 Mm^3/a

The localities of the sources of water listed in Table 5.2 are shown on Figure 1. Descriptions of each source and the type of infrastructure required to deliver water to Queenstown follow.

5.2.1 Raising of Waterdown Dam

Waterdown Dam was originally designed to be raised by 7,0 m, thus increasing the capacity from 21 Mm^3 to 59 Mm^3. This would make additional water available for supplying Queenstown or irrigators. It was calculated in the QRWSFS that an increase in firm yield of 3,6 Mm^3/a could be obtained by such a raising of the dam. The ratio of 1 in 50 year yield to firm yield for Waterdown Dam at its existing capacity has been determined to be 1,2:1 (see Appendix 4 : System Yield Analysis). Thus, multiplying an increase in firm yield of 3,6 Mm^3/a by a factor of 1,2 gives an equivalent increase in 1 in 50 year yield of 4,3 Mm^3/a.

It can be seen from Table 5.1 that an additional supply of 4,3 Mm^3/a would meet the water requirements of Queenstown to well beyond 2045 if the existing spare yield were utilised as well, but to only just beyond the year 2005 if it were allocated to future irrigation from Oxkraal and Shiloh Dams instead (see Table 2.2). In the latter case, an additional source of supply would be required to meet requirements beyond 2005.


Lady Frere
S10D
S10G
Cacadu
S10E
S31D
S31F
Xonxa Dam
S31E
4
Bonkolo Dam
Queenstown
eZibeleni
S32J
S31G
5
S10H
Thornhill
Ilinge
3
S32C
2
S10J
T3
S32K
S32H
6
Whittlesea
T4
S32M
Sada
T6
S32G
1
S32L
Cathcart
S32F
Waterdown Dam
S40C
S32E
S40A
LOCALITY MAP:
LEGEND:
GIS COV:
WMA Boundaries
Waterman
Rivers
Wri500
Dams
Ndams
Quaternary Catchment
Drgnquat
S32K
Quaternary Number
Drgnquat
Secondary Catchment
Drgsnd
Existing Pipeline
Proposed Pipeline
Water Treatment Works
Augmentation Schemes
1 Raising of Waterdown Dam
2 Waklyn Weir
3 Stitchel Weir
4 Pipeline from Xonxa Dam
5 Pipeline from Stitchel/Waklyn Weir
6 New Waterdown Pipeline
T3 Potential Wellfields
PREPARED BY:
NINHAM SHAND
CONSULTING SERVICES
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
GEOGRAPHICAL
SCALE : 1:300 000
4 0 4 8 Km
N
TITLE:
LUKANJI REGIONAL
WATER SUPPLY
FEASIBILITY STUDY
PHASE 2
AUGMENTATION SCHEMES
Prepared by: S.Swartz
Date: 10/2003
Data Type: Augm_schemes_topos.apr
Figure 1

In order to deliver the additional water to Queenstown if the dam were raised, the water transfer capacity would have to be upgraded from the existing 5 Mm^3/a to 9,3 Mm^3/a. As discussed previously, the existing pipeline has a design capacity of 23 Mℓ/day but can deliver a maximum of only 13,7 Mℓ/day while supplying Sada at the same time. According to the QRWSFS, the capacity of the pipeline could be increased by 20% to 27 Mℓ/day by installing an additional pump station. (A booster pump station on the line to Sada would also be required if this were done.). It is assumed that, in order to accommodate seasonal variations in water requirements, and periods when the pipeline is shut down for maintenance, it would be required to deliver water at a peak factor of 1,5 relative to the annual average quantity of water supplied. Thus, at a capacity of 27 Mℓ/day, the average quantity of water delivered would be 6,6 Mm^3/a. The balance of 3,3 Mm^3/a would have to be supplied through a new second pipeline. Alternatively, the existing pipeline could remain as it is, and the new pipeline could be designed to deliver the full additional quantity of water. (It might be advantageous to convey water from Waterdown Dam to Queenstown at a constant rate through a new pipeline of smaller capacity, storing the excess water in Bonkolo Dam during periods of low demand for use during peak demand periods. For simplicity, this option was not considered in the initial comparison of schemes, but it is discussed further in Section 10.3).

A further consideration is that the existing pipeline is forty-five years old and can, therefore, be expected to require refurbishment in the near future. In view of this, it might be economical to abandon the existing pipeline and replace it with a new one that will convey the full 9,3 Mm^3/a of water.

In order to identify the optimum way of augmenting the water supply to Queenstown it is necessary to consider all three of the above options in conjunction with the potential schemes for providing water from other sources that are listed in Table 5.2 and are described below.

5.2.2 A Weir on the Black Kei River at Waklyn

One of the possibilities investigated in the QRWSFS was a storage dam or a diversion weir at Waklyn on the Black Kei River, some 21 km south of Queenstown and upstream of the Klaas Smits River confluence. The present day mean annual runoff at the site is 51 Mm^3/a (QRWSFS), and for the quantity of water required for the Queenstown supply, a diversion weir with a small volume of storage would be more economical than a large storage dam. An analysis carried out for the QRWSFS showed that for a pump station and pipeline capacity of 1,5 m^3/s, a firm yield of about 3,6 Mm^3/a could be obtained if negligible storage were provided by the diversion weir. Alternatively, if 1 Mm^3 of storage were provided by the weir, a yield of 5,7 Mm^3/a could be obtained for a pipeline capacity of 0,5 m^3/s.

The scheme would require a diversion weir, a single pump station, and a 22 km long pipeline to deliver water to the Berry Reservoir in Queenstown.

In the current study, a weir with a storage capacity of 1 Mm^3 was considered in conjunction with a range of pipeline capacities to suit the various schemes in which combinations of water from various sources were considered (see Table 5.3). Amongst the possibilities considered was a scheme in which the existing Waterdown Dam to Queenstown pipeline would be abandoned and water from Waterdown Dam would be released into the river to be intercepted at the Waklyn weir and pumped to Queenstown.

5.2.3 A Weir on the Black Kei River at Stitchel

The feasibility of a storage dam or a weir at Stitchel on the Black Kei River some 17 km south of Queenstown was also investigated in the QRWSFS. This site is downstream of the Klaas Smits River confluence and the present day mean annual runoff is 98 Mm^3/a. According to the QRWSFS, a firm yield of about 7 Mm^3/a could be obtained if a weir with negligible storage were provided, together with a pump station and pipeline of 2 m^3/s. Lower abstraction capacities would be required for the same yield if storage of 1 Mm^3 were provided. As in the case of the Waklyn Weir, the costs of alternative schemes consisting of a weir providing 1 Mm^3 of storage and various different pipeline capacities were investigated.

The advantage of this site relative to the Waklyn site is that lower pumping rates are required for the same yield, because of the higher runoff. A disadvantage is the high silt load that is introduced by the Klaas Smits River. A 15,5 m high weir with large radial scour gates to deal with the silt would be required. The pipeline to Queenstown would be 18 km long and two pump stations would be required to accommodate the lift, which is higher than that at the Waklyn site.

5.2.4 Xonxa Dam

Xonxa Dam lies to the east of Queenstown and, as discussed in Section 3.6, has sufficient unutilised yield to provide an additional 6,6 Mm^3/a at 1 in 50 year assurance. A pipeline between the dam and the Berry Reservoir would be 32 km long, and would pass over Nonesi's Nek, some 10 km east of Queenstown, which would entail pumping against a static head of 430 m by means of two pump stations, one at the dam and one about 19 km from the dam. (In terms of pumping costs, it is of interest to compare this with the Waterdown Dam to Queenstown pipeline which is 48 km long, but has no static head.).

As in the cases of the other sources of supply, a number of schemes incorporating varying quantities of water from Xonxa Dam were costed and compared (see Table 5.3).

5.2.5 Groundwater in the vicinity of Sada

In a review of the groundwater potential of the area, described in detail in Appendix 5, five target areas for the development of wellfields were identified in the vicinity of Sada. Hydrogeological structures are considered to be more favourable in this area than in areas closer to Queenstown. It was estimated that each of these areas could provide sustained yields of 0,9 Mm^3/a, giving a combined yield of 4,5 Mm^3/a.

In considering possible augmentation schemes for Queenstown, this groundwater source was considered as an alternative to raising Waterdown Dam and as a source of water, in conjunction with raising Waterdown Dam, to meet the full estimated additional requirements of Queenstown to 2045.

5.3 PRELIMINARY COMPARISON OF ALTERNATIVE AUGMENTATION SCHEMES

Early in the study, before the magnitudes of the water requirements shown in Table 2.1 had been finalised, a preliminary comparison of the estimated costs of augmentation schemes (excluding the groundwater option) was carried on the basis of providing additional quantities of water of 2,83 Mm^3/a in 1995 and 1,27 Mm^3/a in 2020, i.e. a total increase in the supply of 4,1 Mm^3/a compared to the final estimated water requirement in 2045 of an additional 6,6 Mm^3/a. Even though the estimates of water requirements have increased, the preliminary analysis served the purpose of identifying those alternatives that merit further consideration. The analysis is described in detail in Appendix 6.1 of this report and the results are, therefore, only summarised here.

Sixteen different scheme development options were considered, as outlined in Table 5.3. In Options 1 to 8, it was assumed that the existing Waterdown to Queenstown pipeline would remain in use indefinitely, while Options 9 to 16 assumed that the existing pipeline would be replaced by the first phase of the new scheme. Both the phased implementation of schemes and the initial construction of augmentation schemes to the ultimately required capacity were considered.

TABLE 5.3 SCHEME DEVELOPMENT OPTIONS INVESTIGATED IN THE PRELIMINARY ANALYSIS

OPTION	YEAR		TOTAL CAPITAL COST (R Million)	NPV (R Million)
	2005	2020		
1	Construct Stitchel weir and pipeline (2,83 Mm^3/a)	Construct 2nd Stitchel pipeline (1,27 Mm^3/a)	81	80,06
2	Construct Xonxa pipeline (2,83 Mm^3/a)	Construct Stitchel weir and pipeline (1,27 Mm^3/a)	87	67,57
3	Construct Stitchel weir and pipeline (2,83 Mm^3/a)	Construct Xonxa pipeline (1,27 Mm^3/a)	89	105,66
4	Construct Xonxa pipeline (4,1 Mm^3/a)		34	46,49
5	Construct Waklyn weir and Waklyn pipeline (2,83 Mm^3/a)	Construct 2nd Waklyn pipeline (1,27 Mm^3/a)	87	89,12
6	Boost existing Waterdown pipeline (additional 1,15 Mm^3/a) and construct Xonxa pipeline (2,95 Mm^3/a)		28,6	40,57
7	Construct Xonxa pipeline (2,83 Mm^3/a)	Construct Waklyn weir and Waklyn pipeline (1,27 Mm^3/a)	92	69,57
8	Construct Xonxa pipeline (2,83 Mm^3/a)	Construct Xonxa pipeline (1,27 Mm^3/a)	45	41,97
9	Construct Stitchel weir and pipeline (7,83 Mm^3/a) and decommission Waterdown pipeline	Construct 2nd Stitchel pipeline (1,27 Mm^3/a)	94	116,95
10	Construct Xonxa pipeline (7,83 Mm^3/a) and decommission Waterdown pipeline	Construct Stitchel weir and pipeline (1,27 Mm^3/a)	112	117,57
11	Construct Stitchel weir and pipeline (7,83 Mm^3/a) and decommission Waterdown pipeline	Construct Xonxa pipeline (1,27 Mm^3/a)	97	114,03
12	Construct Xonxa pipeline (9,1 Mm^3/a) and decommission Waterdown pipeline		60	94,24
13	Construct Waklyn weir and Waklyn pipeline (7,83 Mm^3/a) and decommission Waterdown pipeline	Construct 2nd Waklyn pipeline (1,27 Mm^3/a)	99	111,26
14	Raise Waterdown Dam and construct new pipeline (9,1 Mm^3/a) and decommission Waterdown pipeline		118	135,33
15	Construct Xonxa pipeline (7,83 Mm^3/a) and decommission Waterdown pipeline	Construct Waklyn weir and Waklyn pipeline (1,27 Mm^3/a)	117	121,83
16	Construct Xonxa pipeline (7,83 Mm^3/a) and decommission Waterdown pipeline	Construct Xonxa pipeline (1,27 Mm^3/a)	70	100,60

The net present values (NPVs) at discount rates of 3%, 6% and 9% were calculated for each option, taking into account estimated capital, maintenance and running costs. The NPVs at 6%, which is considered to be an appropriate discount rate for present economic circumstances, are shown in the last column of Table 5.3.

Options 1 to 8 all provide the same quantity of water, and their NPVs are, therefore, directly comparable. Options 9 to 16 provide, in addition, the quantity of water that is currently provided by the existing Waterdown pipeline. Consequently, their NPVs are directly comparable with one another, but not with those for Options 1 to 8.

The results of this preliminary analysis show that, for schemes where it is assumed that the existing Waterdown Pipeline will remain in operation indefinitely, Options 6 and 8 are the most economic for augmenting the water supply to Queenstown. The cost of Option 6 is marginally less than that of Option 8 at 6% discount rate. Option 4 is slightly more expensive than both Options 6 and 8, while the other options are significantly more expensive.

Option 6 would entail boosting of the existing Waterdown Pipeline and constructing a single Xonxa pipeline of 300 mm diameter in 2004. Option 8 would entail the phased construction of two Xonxa pipelines, while Option 4 is the construction of a single Xonxa pipeline in place of the two smaller ones of Option 8.

The differences between the NPVs of the three options are small and more detailed investigation was carried out, as described later in this report, to determine the most favourable option.

For the options that entail the decommissioning of the existing Waterdown pipeline when the first scheme comes into operation, Option 12 proves to be the most economical. This is a single 600 mm diameter Xonxa pipeline constructed in 2004, that would supply the water requirements until 2045. At the discount rate of 6%, Option 16 (two phased pipelines from Xonxa Dam to Queenstown) proves to be just slightly more expensive than the single Xonxa pipeline. The other options are all significantly more expensive.

It can be seen from Table 5.3 that the costs of the more economical schemes in which the Waterdown Pipeline is replaced are more than twice the cost of the equivalent schemes in which it is assumed that the pipeline will continue in use indefinitely. This demonstrates the high value of the existing pipeline. It appears from discussion with the Town Engineer of Queenstown that the existing pipeline is reliable and shows no signs of serious deterioration. Therefore, in further investigations of the more favourable schemes, it was assumed that the existing pipeline would remain in operation indefinitely.

When comparing the schemes involving the replacement of the existing Waterdown Pipeline, the NPV of Scheme 14, which involves raising Waterdown Dam and constructing a new 9,1 Mm^3/a capacity pipeline between the dam and Queenstown, is much higher than that of Scheme 12 involving the construction of a single pipeline of equivalent capacity between Xonxa Dam and Queenstown. However, analysis of the costs of individual components of Scheme 14 shows (see Appendix 6.1) that 35% of the NPV is attributable to the capital cost of raising Waterdown Dam.

Thus, the NPV of the capital and operating costs of the pipeline from Waterdown Dam is approximately 65% of the total NPV of Scheme 14 of R135,33 million, which amounts to R88 million. Comparing this value with the NPV of R94,24 million for Scheme 12 for the equivalent pipeline from Xonxa Dam, suggests that a second pipeline from Waterdown Dam might be more economical if additional water could be made available at a significantly lower cost than that of raising the dam. Therefore, various alternatives were considered, as described below.

5.4 POSSIBILITIES FOR INCREASING THE SUPPLY TO QUEENSTOWN FROM WATERDOWN DAM

The estimated water requirement of Queenstown in 2045 is 6,60 Mm^3/a higher than the capacity of the present supply, as shown in Table 5.1. The supply would be required at 1:50 year assurance.

As discussed in Section 3.5, an extra 3,72 Mm^3/a of water could be made available to Queenstown from Waterdown Dam if irrigation supplies were limited to the requirements in 2005 and the Reserve of 3,7 Mm^3/a were released from Waterdown and Oxkraal Dams. The additional requirement of 2,88 Mm^3/a might be obtained by :

(i) purchasing allocations of irrigation water, or
(ii) developing a groundwater supply for Sada.

5.4.1 Purchase of irrigation allocations

The potential for purchasing water allocations from farmers supplied from Waterdown Dam was investigated. The farmers, through their representatives, were consulted on their willingness to sell water allocations at about R7 000/ha. The amount was calculated, as shown in Table 5.4, from the difference in estimated costs between a Xonxa Scheme and a Waterdown Scheme with no raising of the dam, and the number of hectares worth of water allocations that would be required to obtain the additional quantity of water required. The farmers did not want to sell at that price. Without the purchase of water allocations, there will be insufficient water available from Waterdown Dam to meet the future requirements of Queenstown without augmentation from another source.

TABLE 5.4 ECONOMIC PRICE FOR PURCHASE OF WATER ALLOCATIONS

NPV at 6% of Scheme 12 (Xonxa) is R94 243 602
NPV at 6% of Scheme 14 without raising Waterdown Dam is R90 487 948

Thus, if Waterdown Dam is not raised, there will be a saving in cost of approximately R4 million, but an additional 4,1 million m^3/a of water will need to be obtained by purchasing water allocations.

Water allocations are assumed to be 6 100 $m^3/ha/a$ + 25% allowance for river losses = 7 625 $m^3/ha/a$ at 1:10 year assurance.

Equivalent quantity at 1:50 year assurance = 7 625 x 0,83 = 6 328 $m^3/ha/a$.

No. of ha of allocations to be purchased = $\frac{4100000}{6328}$ = 648 ha

= R6 153/ha

5.4.2 Groundwater supply for Sada

In a review of the groundwater potential of the area, described in detail in Appendix 5, five target areas for the development of wellfields were identified in the vicinity of Sada. Hydrogeological structures are considered to be more favourable in this area than in areas closer to Queenstown. It was estimated that each of these areas could provide sustained yields of up to 1,2 Mm^3/a by means of eight production boreholes, each delivering 5 ℓ/s for 19 hours per day.

The three most favourable of these, in terms of costs of development and favourable hydrogeological are situated close to Sada. These three target areas are designated T4, T5 and T6 on Figure 1, and could provide the 3 Mm^3/a of water that it is estimated that Sada will require by 2045. In that case, the allocation of 3,0 Mm^3/a from Waterdown Dam to Sada could be transferred to Queenstown. This, together with the 3,72 Mm^3/a of potential additional yield available from Waterdown Dam (see Table 5.1), would make 6,72 Mm^3/a of yield available for Queenstown, and would meet its estimated requirements to beyond 2045. In view of this, a scheme with a groundwater component was one of the alternatives included in the final comparison of potential augmentation schemes.

6. FINAL COMPARISON OF AUGMENTATION OPTIONS

For the reasons discussed in Section 5.3, where the preliminary comparison of augmentation schemes was described, schemes in which the existing Waterdown to Queenstown pipeline would be abandoned were not considered further, and, because of their high cost, neither were schemes that would require the construction of a diversion weir on the Black Kei River. Thus, all the options that were considered involved retaining the existing supplies from Waterdown and Bonkolo Dams with augmentation from either Waterdown or Xonxa Dams, or both. In addition, the possibility was considered of supplying Sada with groundwater and thereby making more water from Waterdown Dam for the supply to Queenstown.

The principal details of the options considered are shown in Table 6.1.

Option A allows for a new 400 mm diameter pipeline from Waterdown Dam to Queenstown to deliver the additional 3,7 Mm^3/a of water that is available from Waterdown Dam if it is assumed that the allocation of water to irrigation will not be increased in future. This would bring the assured supply to Queenstown to 9,6 Mm^3/a. An additional 0,5 Mm^3/a from another source would be required to bring the available supply at 1:50 year assurance to the requirement in 2005 of 10,05 Mm^3/a. (This quantity includes 2,2 Mm^3/a to replace the existing borehole supplies to Ilinge and the Macibini villages).

In order to meet this requirement and the expected growth in requirements to the year 2015, a 300 mm diameter pipeline, with pumps to deliver 1,1 Mm^3/a, to be constructed in 2005 between Xonxa Dam and Queenstown, has been allowed for. Thereafter, the construction in 2015 of a second 300 mm diameter pipeline, also from Xonxa Dam, but with pumps sized to deliver 1,8 Mm3/a, has been allowed for to meet the water requirements to the year 2045.

The net present value of this scheme is estimated to be R176 million, and the unit reference value for water provided R1-08/m^3, both at discount rates of 6% per annum.

Option B is a variation on Option A in which a pipeline of sufficient diameter (500/400 mm) to convey the 2045 water requirement from Xonxa Dam is constructed in 2005, and pumping capacity is boosted in further phases in 2015 and 2030.

This approach, with a net present value of R156 million Rand, and a unit reference value of R1-00/m^3, is more economical than Option A, which would entail the phased construction of two separate pipelines from Xonxa Dam to Queenstown.

TABLE 6.1 PRINCIPAL DETAILS OF FINAL AUGMENTATION OPTIONS CONSIDERED

Options	Component	Capacity (Mm^3/a) in Year					Capital Cost (R million)	Annual Operating Cost at Full Capacity (R million)	Net Present Value at 6% (R million)	Unit Reference Value (R/m^3)
		2005	2015	2020	2030	2045				
A	Bonkolo Pipeline	0,9	0,9	0,9	0,9	0,9	*	*	*	*
	Existing Waterdown Pipeline	5,0	5,0	5,0	5,0	5,0	*	*	*	*
	Second Waterdown Pipeline	3,7	3,7	3,7	3,7	3,7	79,85	1,06		
	Xonxa Pipeline (300 mm dia)	1,1	1,1	1,1	1,1	1,1	47,33	0,78		
	Second Xonxa Pipeline (300 mm dia)	--	1,8	1,8	1,8	1,8	47,80	1,35		
	Total Scheme Capacity	10,7	12,5	12,5	12,5	12,5	174,98	3,19	176	1,08
	Water requirements	10,1	10,7	11,0	11,6	12,5				
B	Bonkolo Pipeline	0,9	0,9	0,9	0,9	0,9	*	*	*	*
	Existing Waterdown Pipeline	5,0	5,0	5,0	5,0	5,0	*	*	*	*
	Second Waterdown Pipeline	3,7	3,7	3,7	3,7	3,7	79,85	1,06		
	Xonxa Pipeline (400/300 dia)	1,1	1,1	1,1	1,1	1,1	50,95	0,79		
	Xonxa Pipeline boosted	--	1,0	1,0	1,0	1,0	1,02	0,82		
	Xonxa Pipeline boosted	--	--	--	0,8	0,8	1,58	1,00		
	Total scheme capacity	10,7	11,7	11,7	12,5	12,5	133,40	3,67	156	1,00
	Water requirements	10,1	10,7	11,0	11,6	12,5				
C	Bonkolo Pipeline	0,9	0,9	0,9	0,9	0,9	*	*	*	*
	Existing Waterdown Pipeline	5,0	5,0	5,0	5,0	5,0	*	*	*	*
Wellfields	Existing Waterdown boosted	1,15	1,15	1,15	1,15	1,15	0,35	0,18		
T4 & T6	Groundwater to Sada (2,5 Mm^3/a in 2 equal phases)	**		**			20,85	0,72		
	Second Waterdown Pipeline	3,65	3,65	3,65	3,65	3,65	90,58	1,04		
	Second pipeline boosted	--	1,0	1,0	1,0	1,0	1,62	0,86		
Wellfield	Second pipeline further boosted	--	--	--	0,8	0,8	1,54	1,18		
T3 + pipeline	Third groundwater scheme for Sada (0,5 Mm^3/a)				**		7,35	0,12		
	Total Queenstown Scheme capacity	10,7	12,0	12,0	12,5	12,5	122,29	4,10	127	0,78
	Queenstown water requirements	10,1	10,7	11,0	11,6	12,5				

* Costs are not included as these components are common to all the schemes

** Yields are not included in the totals because the wellfields supply Sada, thereby making more water available to Queenstown from Waterdown Dam.

*** Design flow rates for proposed pipelines are 1,5 times the capacities quoted.

TABLE CONTINUED OVERLEAF

TABLE 6.1 CONTINUED

Options	Component	Capacity (Mm^3/a) in Year					Capital Cost (R million)	Annual Operating Cost at Full Capacity (R million)	Net Present Value at 6% (R million)	Unit Reference Value (R/m^3)
		2005	2015	2020	2030	2045				
D	Bonkolo Pipeline	0,9	0,9	0,9	0,9	0,9	*	*	*	*
	Existing Waterdown Pipeline	5,0	5,0	5,0	5,0	5,0	*	*	*	*
	Xonxa Pipeline (400 mm dia.)	4,8	4,8	4,8	4,8	4,8	67,35	3,80		
	Second Xonxa Pipeline (300 mm dia.)	--	1,8	1,8	1,8	1,8	47,80	1,36		
	Total Scheme Capacity	10,7	12,5	12,5	12,5	12,5	115,15	5,16	148	0,90
	Water requirements	10,1	10,7	11,0	11,6	12,5				
E	Bonkolo Pipeline	0,9	0,9	0,9	0,9	0,9	*	*	*	*
	Existing Waterdown Pipeline	5,0	5,0	5,0	5,0	5,0	*	*	*	*
	Xonxa Pipeline (500/400 mm dia.)	4,8	4,8	4,8	4,8	4,8	68,00	3,55		
	Xonxa Pipeline boosted	--	1,0	1,0	1,0	1,0	1,37	1,15		
	Xonxa Pipeline further boosted	--	--	--	0,8	0,8	1,50	0,81		
	Total Scheme Capacity	10,7	11,7	11,7	12,5	12,5	70,87	5,51	122	0,74
	Water requirements	10,1	10,7	11,0	11,6	12,5				

Option C allows for the water supply to be augmented from Waterdown Dam only. The water requirement in 2045 of 2,9 Mm^3/a that is additional to the 8,7 Mm^3/a that is currently available to Queenstown from Waterdown Dam would be obtained by the phased development of wellfields to supply Sada, thereby making the water that would otherwise be supplied to it from Waterdown Dam available for the Queenstown supply. The first phase of construction, assumed for purposes of the financial comparison to occur in 2004, would entail :

- boosting of the existing Waterdown to Queenstown pipeline to deliver an extra 1,15 Mm^3/a (the maximum obtainable without exceeding the pressure rating of the pipeline);
- constructing a second pipeline between Waterdown Dam and Queenstown with pump stations initially sized to deliver 3,65 Mm^3/a, but designed to be boosted in two phases to a maximum capacity of 5,4 Mm^3/a.

The intention to develop a wellfield to supply Sada would allow the 0,59 Mm^3/a of the yield of Waterdown Dam, which was assumed in the analysis in Section 3.5 to be allocated to the future requirements of Sada, to be used for the Queenstown supply immediately. Consequently, taking account of the predicted growth in the water requirements of both Queenstown and Sada, delivery from the proposed wellfield will only be required from 2008 onwards. The requirement from the wellfield is expected to be 0,02 Mm^3/a in 2008, increasing to 2,53 Mm^3/a by 2041, and 2,88 Mm^3/a by 2045. Therefore, for purposes of this analysis, it has been assumed that a wellfield with a sustained yield of 1,25 Mm^3/a would be commissioned in 2007 (in target area T6 as described in Appendix 5) with a second wellfield with a sustained yield of 1,25 Mm^3/a being developed in 2022 (target area T4) and a third, with a yield of 0,5 Mm^3/a being commissioned in 2040 (assumed to be in target area T3).

The delivery of the second pipeline between Waterdown Dam and Queenstown would be increased in stages by increasing the pumping capacity in 2020 and 2030 to increase the capacity to 5,4 Mm^3/a.

This scheme would have a net present value of R127 million and a unit reference value of R0-78/m^3.

Options D and E allow for all augmentation of the Queenstown water supply to be from Xonxa Dam, i.e. the supply from Waterdown Dam would be fixed at the present 5 Mm^3/a. Option D allows for the construction of a 400 mm diameter pipeline between Xonxa Dam and Queenstown in 2005, followed by a second pipeline of 300 mm diameter in 2015. Option E allows for a 500 mm/400 mm diameter pipeline to be constructed in 2005 with pumping capacity boosted in 2015 and again in 2032. (As in the case of a new pipeline from Waterdown Dam, discussed in Section 5.2.1, the size of the pipelines from Xonxa Dam could be reduced by delivering water at a constant rate and storing it in Bonkolo Dam during periods of low demand for use in periods of peak demand. For simplicity, this refinement has not been included in the comparison of schemes, but it is discussed further in Section 10.3).

Option E is the more economical of the two, with a net present value of R126 million and a unit reference value of R0-77/m^3.

The bases for the design of the conceptual schemes and the cost estimates are described in Section 7 and 8, respectively. Tables showing the calculation of net present values are contained in Addendum 6.3.

7. DESIGN PARAMETERS

The same design parameters that were used for the QRWSFS were used for this study, except that the QRWSFS considered only steel pipes, while a combination of steel pipes for areas of higher pressures and glass fibre reinforced polyester (GRP) were considered in areas of lower pressures because the latter are more economical than steel for the pipe diameters required.

7.1 PIPELINES

Only steel pipelines were considered where design pressures, including a 30% allowance on normal working pressures for waterhammer effects, exceeded 250 m water head. Only GRP pipes were considered where design pressures were less than 250 m water head.

Wall thicknesses for steel pipes were determined from the formula:

$T = (P*D)/f_y$

where
T = wall thickness in mm (subject to minimum thicknesses as shown below)
D = diameter of pipe
P = pressure(MPa); total pumping head- pumping mains, static head- gravity mains
f_y = yield stress of steel assumed to be 300 N/mm^2

Minimum pipe wall thicknesses were assumed in accordance with British Standard 534:1990 as follows :

200 mm and 300 mm diameter	4,0 mm
400 mm and 500 mm diameter	5,0 mm
600 mm diameter	6,3 mm

GRP pipes were considered for the commercially available pressure classes of 100 m, 160 m and 250 m water head.

Longitudinal sections were obtained from the QRWSFS. These were determined at 100 or 200 m intervals and obtained from 1:10 000 orthophoto mapping for the Xonxa pipeline, but off 1:50 000 topocadastral mapping for the existing and replacement Waterdown Pipeline.

A design flow rate of 1.5 times the average annual daily demand was used.

7.2 PUMP STATIONS

The maximum single head was assumed to be 250 m. If the total head exceeded this, additional pump stations were situated at convenient points.

The total pump head (H) was calculated as:

$$H = H\ static + H\ pump + H\ sec + H\ friction$$

where

H static = static head

H pump = 4 m per pump station

H sec = 1 m per km of rising main

H friction = friction loss computed by Hazen Williams formula with C = 110 or 120, depending on the pipe diameter

8. COSTING

The various infrastructure components associated with each of the scheme development options were costed at 2003 rates. The following approach was used.

8.1 PIPELINES

Updated costs for steel pipelines, based on recent tenders and information from manufacturers were used. Unit rates, which include material and installation costs, are as shown in Table 8.1.

TABLE 8.1 UNIT RATES FOR COSTING OF PIPELINES

STEEL PIPES		
DIAMETER (mm)	**WALL THICKNESS (mm)**	**RATE (R/m)**
300	4,0	635
400	5,0	993
500	5,0	1 230

GRP PIPES			
DIAMETER (mm)	**PN 10 RATE (R/m)**	**PN 16 RATE (R/m)**	**PN 25 RATE (R/m)**
300	546	565	597
400	629	654	704
500	984	1020	1 107

Note: Rates include costs of pipe, excavation, laying, backfilling, specials, thrust blocks, valves and chambers but exclude site establishment, contingencies, design fees and VAT.

8.2 PUMP STATIONS

Pump station costs were calculated based on the formula that was used in the QRWSFS and which originated in the Vaal Augmentation Planning Study (DWAF, 1994), after which they were escalated to 2003 prices:

$$\text{Cost} = A * H^{8} * Q$$

where

A = 182 000

B = 0.65

Q = flow rate in m^3/s

H = total head pumped

The following allowances were assumed:

Civil cost	30	% of capital cost
Mechanical cost	50	% of capital cost
Pump and motor cost	60	% of mechanical cost
Electrical cost	20	% of capital cost
Maintenance cost (M&E)	4	% of mechanical & electrical cost
Maintenance cost (Civil)	0.25	% of civil cost
Operational costs	0.15	% of the total capital cost.

Energy costs were calculated as:

Basic:	R292.86/month
Power:	R62.9/kVA/month
Energy:	R 0.12/kWh

Energy costs were calculated using the simplifying assumption that the water levels in the dams were at minimum operating levels at all times and overall pumping efficiencies of 85%. This does not affect the relative costs of the schemes as the total pumping heads of all schemes would be reduced by about 3% if the average dam water levels were assumed to be at mid-operating level.

8.3 APPURTENANT WORKS

An allowance of R5 million before the addition of site establishment, contingencies and VAT was made for each pipeline to cover appurtenant works such as access tracks, flow meters and road and river crossings.

8.4 SITE ESTABLISHMENT, CONTINGENCIES AND VAT

The following additional allowances in addition to the basic construction costs were made :

Site establishment	30% of basic construction cost
Contingencies	10% of basic construction cost plus site establishment
VAT	14% of total cost

8.5 PROFESSIONAL FEES

Design fees were calculated as the normal percentage fee. Allowances for construction supervision of R2 million for the Xonxa pipelines and R2,5 million for the Waterdown pipelines were made. Contingencies at 10% and VAT at 14% were added to these.

8.6 POWER SUPPLIES

Allowances for power supplies of R2 million were made for each pipeline. Contingencies at 10% and VAT at 14% were added.

8.7 WELLFIELDS

Since a groundwater development project differs significantly from other civil engineering projects, the unit costs and percentages for contingency and professional fees were established independently of unit costs for surface water schemes. Tables 8.1 to 8.6 show the unit costs used in calculating the civil capital costs for the wellfield developments.

The unit costs for borehole construction (see Table 8.2) depend upon several factors (e.g. required depth, lithology, required end-diameter), most of which are unknown or uncertain at present. The proposed unit costs per meter are based on costs of recent drilling projects in a similar geological environment and include

- establishment on site;
- drilling in different diameters;
- installation of steel casing, if required;
- installation of PVC casing;
- construction of wellhead.

The unit costs for pumptesting (see Table 8.2) depend upon the expected yield of the borehole. It was assumed that each production borehole would be tested according to the SABS standards. In addition a longer-term wellfield test for each wellfield is allowed for.

TABLE 8.2 UNIT COSTS AND ASSUMPTIONS FOR BOREHOLE DRILLING AND PUMPTESTING

DESCRIPTION	YIELD ℓ/s	DEPTH DRILLING M	UNIT PRICE R/m	DRILLING COSTS R/BH	PUMP-TESTING R/Test
1 Borehole, Production	2	150	700.00	105 000.00	1500.00
1 Borehole, Production	5	200	800.00	160 000.00	2000.00
1 Borehole, Monitoring		150	600.00	90 000.00	
1 Wellfield					100 000.00

The capital costs for the borehole pumps (see Table 8.3) depend upon the assumed yield and the required hydraulic head. For all wellfields a hydraulic head of 50 m was assumed.

The electricity costs are calculated using the current Eskom tariff structure.

TABLE 8.3 UNIT COSTS AND ASSUMPTIONS FOR PUMP INSTALLATION AND RUNNING COSTS

DESCRIPTION	YIELD ℓ/s	ELECTRICITY REQUIREM. KW	UNIT PRICE R/KWh	RUNNING COSTS R/BH/h	PUMP-COSTS R/Pump
1 Borehole, Production	2	20	0.140	2.81	30 000.00
1 Borehole, Production	5	30	0.140	4.21	40 000.00

The required pipe diameter for the pipelines within the wellfields depends upon the assumed flow rates, as estimated above. The costs for the pipelines (see Table 8.4) are based on costs from 2003 and include the capital cost and all work required for installation, e.g. trenching, valves, manholes. Since the latter is proportionally higher for small pipeline diameters and the choice of pipeline diameter within the wellfield may be arbitrary, all pipelines smaller than 100 mm are assumed the same unit costs as the 100 mm pipeline.

TABLE 8.4 UNIT COSTS AND ASSUMPTIONS FOR PIPELINES WITHIN THE WELLFIELDS

DESCRIPTION	FLOW ℓ/s	AVERAGE VELOCITY m/s	REQUIRED PIPE DIA. mm	PIPE DIAMETER mm	PIPE COST R/m
1 Borehole, small	2	1.5	41.2	50.0	420.00
1 Borehole, big	5	1.5	65.1	75.0	420.00
1 Wellfield, safe	10	1.5	92.1	100.0	420.00
1 Wellfield, realistic 1	20	1.5	130.3	200.0	880.00
1 Wellfield, realistic 2	40	1.5	184.3	200.0	880.00

For the annual maintenance the percentages normally used in DWAF studies are applied (see Table 8.5).

TABLE 8.5 PERCENTAGES FOR MAINTENANCE COSTS

DESCRIPTION	MAINTENANCE	
	CIVIL	MECHANICAL ELECTRICAL
1 Wellfield	0.25%	4%

The percentages for Site Establishment, Contingencies and Professional Fees, as used in civil engineering projects, are not applicable for a groundwater development project. Therefore they were adjusted accordingly (see Table 8.6). The main reasons are:

- During drilling and pumptesting, which are the main activities for a wellfield development, no additional Site Establishment costs occur, as these are already included in the unit costs.
- Due to the incremental approach for wellfield development the contingencies are increased at this stage of the project.
- Since the investigation of groundwater potential was undertaken at a pre-feasibility level, additional investigation, planning and supervision is required during the exploration and establishment phases.

TABLE 8.6 PERCENTAGES FOR SITE ESTABLISHMENT, CONTINGENCIES AND PROFESSIONAL FEES

Description	Additional Costs		
	P&Gs	Contingencies	Planning and Supervision
1 Wellfield	1%	25%	30%

In addition to the unit costs listed in Tables 8.1 to 8.5, fixed costs for power supply and access routes to the proposed wellfields and costs for compliance with environmental regulations are included in the different scenarios (see below).

The costing of the different wellfield options was undertaken only for the selected target areas, as listed in Section 4.4.1 of Appendix 5; *viz*. T1, T3, T4, T5 and T6. Based on the assumptions mentioned above and a general wellfield design within the target area, the development costs and the operational costs were calculated for two different yield scenarios, one assuming a total yield of 0.6 million m^3/a and a borehole yield of 2 ℓ/s, and the second assuming a total yield of 1.2 million m^3/a and a borehole yield of 5 ℓ/s. In Augmentation Scheme Option C, the less conservative borehole yield of 5 ℓ/s was used.

The development costs include capital costs, professional fees, and environmental services. Environmental services are estimated based on experiences on other water supply projects, mainly involving surface water structures and major infrastructure.

No allowance in the capital costs was made for 'dry' boreholes, because all boreholes drilled will be sited and drilled in stages from exploration to production. Exploration boreholes can either become production boreholes, if successful, or monitoring boreholes. The increased contingencies and professional fees account for this approach.

The site establishment costs include R100,000 per wellfield for constructing access roads and to permanently supply electricity.

The running costs include electricity for the pumps and general maintenance. Additional operational costs, such as monitoring or water treatment were not costed at this stage of the project, as it is assumed that these will be the same for all options.

9. CONCLUSIONS

It is anticipated that the water requirements of Queenstown will grow from 10,1 Mm^3/a in 2005 to 12,5 Mm^3/a in 2045, including the 2,2 Mm^3/a requirements of Ilinge and the Macibini Villages which are currently served by boreholes. The requirements of Sada will grow from 2,41 Mm^3/a to 3,0 Mm^3/a over the same period.

It has also been assumed that the potential maximum irrigation water requirement from Waterdown Dam of 14,68 Mm^3/a (equivalent 1:50 year requirement of 12,18 Mm^3/a) will be provided from Waterdown, Bushmanskrantz, Oxkraal and Shiloh Dams, and that none of the possible future irrigation developments that could be supplied with water from Bushmanskrantz, Oxkraal and Shiloh Dams will be implemented. It is emphasised that this assumption was made purely for purposes of comparing possible augmentation schemes and in no way precludes the development of additional irrigated lands in future.

It has also been assumed that combined Reserve releases of 3,7 Mm^3/a will be made from Waterdown and Oxkraal Dams.

On this basis, the shortfall in the availability to Queenstown of water from these dams and Bonkolo Dam combined will increase from 0,43 Mm^3/a in 2005 to 2,88 Mm^3/a in 2045. In addition, there is currently a shortfall in pipeline capacity to meet the peak demand, assumed to be 50% greater than the average annual demand.

It was shown in the preliminary comparison of augmentation schemes, described in Section 5.3, that the existing pipeline between Waterdown Dam and Queenstown is of high economic value. Therefore, it is likely to remain in service for the foreseeable future, even though it is now forty-five years old, as it is reported to still be in good condition. The preliminary comparison also showed that augmentation of the Queenstown water supply from a new dam or diversion weir to be constructed on the Black Kei River would be considerably more costly than augmentation from the existing Xonxa Dam, or from the existing Waterdown Dam, if sufficient water could be made available.

The investigations carried out for this study have shown that there is sufficient unallocated water available from Xonxa Dam to meet the expected increase in the water requirements of Queenstown to beyond the year 2045.

With the availability of water from Oxkraal Dam to provide some of the water for irrigation previously provided from Waterdown Dam, there is currently (2005) unutilised yield from Waterdown Dam that could be used to augment the water supply to Queenstown, as summarised above. On the basis of the assumptions described above in respect of the availability of water, the quantity is insufficient to meet the expected increase in the requirements of Queenstown to the year 2045, and a supplementary source would be required to do so. The preliminary assessment of possible augmentation schemes has shown that it would not be economical to supplement the raw water supply by raising Waterdown Dam. However, a pre-feasibility level desktop assessment of groundwater potential in the area has shown good prospects for the development of wellfields in the vicinity of Sada. Therefore, the possibility was considered of increasing the quantity of water that could be supplied to Queenstown from Waterdown Dam by developing a groundwater supply for Sada, and thereby making available for the Queenstown supply the water currently supplied to Sada from Waterdown Dam.

The results of financial comparisons of schemes to augment the Queenstown supply from this potential groundwater source with schemes to augment it from Xonxa Dam are shown in Table 6.1. It can be concluded from the information presented in the table that:

- it would be more economical to construct a pipeline between Xonxa Dam and Queenstown sized initially to convey the full quantity of water required in the year 2045 than to construct two smaller pipelines in phases (Options A and B and Options D and E);
- in terms of the unit reference values for water supplied over the period from 2005 to 2045, there would be little difference between augmentation from Waterdown Dam, with a new groundwater supply included (Option C), and augmentation entirely from Xonxa Dam;
- augmentation partially from Waterdown Dam, (without groundwater supply) and partially from Xonxa Dam (Option B) would cost about 30% more, in terms of unit reference values, than augmentation exclusively from either of the sources (Option C or Option E).

In view of the above, it is necessary to make a choice between augmentation from Waterdown Dam (Option C) and augmentation from Xonxa Dam (Option E). The choice is made easier by certain advantages which are apparent in the Xonxa Dam option, namely:

(i) The raw water source already exists, whereas the groundwater source for the Waterdown Dam option has still to be proved in the field, and the cost of developing it may be significantly higher than estimated.

(ii) The initial capital cost of the Xonxa Pipeline, estimated to be R68 million, is considerably lower than the estimated R90 million for the Waterdown Pipeline, and it would, therefore, be easier to finance. (The disadvantage is that the Xonxa Pipeline pumping costs would be higher than those from Waterdown Dam).

(iii) A supply from Xonxa Dam would be from a completely separate source, which would reduce the risk of complete disruption of the supply in the event of a natural disaster.

(iv) There is unutilised yield available from Xonxa Dam, whereas the additional water that would be used from Waterdown dam could also be beneficially used for irrigation by small scale farmers.

(v) Xonxa Dam lies in a region with different hydrological characteristics to the region in which Waterdown Dam is situated. Droughts in the two regions do not have a high correlation, and this is a factor that has benefits for the operation of the system.

For the above reasons, augmentation from Xonxa Dam is preferred to augmentation from Waterdown Dam.

10. OTHER FACTORS CONSIDERED

It the course of the investigations certain factors were considered that were not taken into account in the comparison of possible augmentation schemes because they did not significantly affect the relevant costs. Nevertheless, some of them merit consideration when carrying out the detailed design of the first phase of the augmentation scheme. The factors are:

- The possibility of supplying the Sada Water Treatment Works with raw water from Oxkraal Dam.
- Constructing a booster pumpstation on the existing pipeline to Sada.
- Using Bonkolo Dam as balancing storage to reduce the rate of pumping from Xonxa or Waterdown Dams.
- Supplying rural villages along the route of the pipeline from Xonxa Dam to Queenstown.
- Retaining the existing borehole supply to Ilinge.

Each of these factors is discussed briefly below.

10.1 SUPPLY TO SADA FROM OXKRAAL DAM

The Sada Water Treatment Works is about 15 m above the full supply level of Oxkraal Dam. Therefore, while it would be feasible to supply water from Oxkraal Dam, the whole supply would have to be pumped, and a new pump station and 4 km long pipeline would have to be constructed. The full supply level of Waterdown Dam, on the other hand, is about 30 m above the level of the water treatment works, so that, even though a new pump station is required on the existing pipeline, water could be supplied by gravity alone for part of the time and pumping costs would be lower. In addition, no new pipeline would be required. Finally, as Oxkraal and Waterdown Dams both supply irrigation water to the same areas via releases into the river channel, there would be no benefit, in terms of increasing the available yield, in supplying the treatment works from Oxkraal Dam.

It is concluded from the above that there would be no advantage in supplying the Sada Water Treatment Works from Oxkraal Dam. It would be more economical to construct a booster pump station on the existing branch from the Waterdown Dam to Queenstown Pipeline.

10.2 BOOSTER PUMP STATION ON THE EXISTING PIPELINE TO SADA

The cost of a booster pump station on the Sada pipeline has not been investigated in this study because in the alternative augmentation schemes considered, the existing supply to Sada was assumed to be replaced by a groundwater supply, with the result that a booster pump station was not required. However, if, as seems probable, it is decided to augment the supply to Queenstown from Xonxa Dam, the implications of providing a booster pump station on the pipeline to Sada should be considered when optimising the detailed design of the augmentation scheme. Factors to consider are:

(i) As the water requirements of Sada increase, it may be necessary to provide a booster pump station in order to be able to maintain the current level of supply to Queenstown. Alternatively, it might be more economical to continue to supply Sada without boosting and to decrease the supply from Waterdown Dam to Queenstown slightly, while compensating for this by supplying slightly more water from Xonxa Dam.

(ii) Conversely, because pumping costs from Xonxa Dam would be about 40% higher than from Waterdown Dam, it might be economical to provide booster pump stations on both of the existing Sada and Waterdown Dam to Queenstown pipelines and reduce the quantity of water pumped from Xonxa Dam.

10.3 USING BONKOLO DAM AS BALANCING STORAGE TO REDUCE THE RATE OF PUMPING FROM XONXA DAM

The capacity of Bonkolo Dam is more than twice the present day mean annual runoff into the dam. As the route of the proposed pipeline from Xonxa Dam to Queenstown would pass close to Bonkolo Dam, it may be feasible to use Bonkolo Dam as balancing storage for the water transferred from Xonxa Dam. This would allow water to be pumped from Xonxa Dam at a lower peak factor and would reduce pumping costs and, probably, the capital cost of the pipeline.

The quantity of water that could be pumped into Bonkolo Dam without significantly increasing the risk of losing more water through spillage of the dam, is addressed in Appendix 4 : System Yield Analysis. The evaluation of the possible financial benefits of adopting this approach should be part of the optimisation of the detailed design, if it is decided to implement an augmentation scheme from Xonxa Dam.

Similarly, by means of a cross-connection from the Waterdown pipeline to the pipeline between Bonkolo Dam and the Queenstown Water Treatment Works, excess flow in the pipeline could be diverted into Bonkolo Dam for storage, to be fed back to the treatment works during times of peak demand. As discussed in Section 8.1, by boosting the existing pipeline and the branch to Sada, the delivery through the existing pipeline could be increased from the present 5,0 Mm^3/a to 8,9 Mm^3/a by operating the pipeline continuously at full capacity. The delivery of 8,9 Mm^3/a might be reduced to 8,7 Mm^3/a by the availability of water from Waterdown Dam (the 3,7 Mm^3/a that is not used for irrigation at present). A supply of 8,7 Mm^3/a would still require the implementation of an additional augmentation scheme in 2005. However, as in the case of the Xonxa pipeline discussed above, this approach would reduce the required capacity of the augmentation scheme.

The indications from discussions held with the Department of Agriculture and the Chris Hani District Municipality during the course of this study were that the lands for which Bushmanskrantz and Shiloh Dams were built to provide water for irrigation are highly likely to be developed in the near future. Consequently, no additional water to the 5,0 Mm^3/a currently used from Waterdown Dam is likely to be available to Queenstown from this source in future. Therefore, the possibilities, discussed above, of boosting the existing Waterdown pipeline and storing water from the pipeline in Bonkolo Dam are unlikely to be practical.

10.4 SUPPLYING RURAL VILLAGES ALONG THE ROUTE OF A PIPELINE FROM XONXA DAM TO QUEENSTOWN

The possibility of supplying rural villages in the vicinity of Xonxa Dam from a pipeline between Xonxa Dam and Queenstown was considered. Disadvantages of such an arrangement would be that the offtakes for the villages would add to the complexity of the pipeline design and operation, and several small water treatment works would be required to provide potable water to the villages.

It is understood that, as a result of a separate study commissioned by Chris Hani District Municipality, it is likely that these villages will be supplied from groundwater sources. The results of the investigation into supplying the villages from the proposed pipeline are, nevertheless, recorded below for future reference.

Xonxa Dam is situated in a valley surrounded by steep hills that limit the number of rural villages upstream of the dam wall that it might be feasible to supply from the dam to fourteen in number. The total number of people living in the villages is about 40 000 according to the figures provided by the National Demographic Study commissioned by DWAF in 2000. Five of these villages to the north of Xonxa Dam are supplied or intended to be supplied by the Cacadu Regional Water Supply Scheme. The feasibility of supplying the other villages from the proposed Xonxa Dam to Queenstown pipeline was investigated in detail in 1996 by UWP in a study commissioned by DWAF. The estimated costs of supplying the villages from the proposed pipeline were compared with the estimated costs of groundwater supplies. It was found feasible to supply the six villages listed in Table 10.1, which also shows predicted future populations and estimated water requirements, including those of livestock.

TABLE 10.1 RURAL VILLAGES THAT COULD BE SUPPLIED WITH RAW WATER FROM THE XONXA PIPELINE

VILLAGE NAME	CODE	POPULATION IN YEAR			LIVESTOCK (ELSU)*	WATER REQUIREMENTS** (kℓ/d)		
		1995	2005	2015		1995	2005	2015
Xonxa	E011	7 810	9 384	10 050	4 510	363	406	424
Hatini	E010	1 469	1 765	1 890	1 716	96	104	108
Egcibhala	E012	2 198	2 641	2 828	1 270	102	115	120
Gandu	E013	1 266	1 521	1 629	732	59	66	69
North of Ndenxe	E008	4 348	5 224	5 595	796	146	170	180
Ndenxe	E009	1 068	1 283	1 374	848	58	63	66
Totals		18 159	21 818	23 366	9 872	824	924	967

* ELSU = equivalent large stock unit. Water requirement assumed to be 30 ℓ/d/unit plus 10% losses.

** Human requirement assumed to be 25 ℓ/person/day plus 10% losses.

The village populations in 1995 were taken from the UWP report as they agreed approximately with the values given by the National Demographic Study which were correlated with the 1996 Census figures. Growth in population after 1995 was calculated using the growth rates predicted in the National Demographic Study. Equivalent large stock units were taken from the UWP report and assumed to remain constant, as the area is fully stocked.

It is assumed that water requirements will remain constant after 2015. The requirement of 967 kℓ/day equates to 0,35 Mm^3/a. For pipeline design purposes, a capacity of 970 kℓ/day at a peak factor of 1,5 has been assumed. Thus the additional capacity required in the Xonxa pipeline to serve the rural villages would be a maximum of 16,8 ℓ/s. This requirement would reduce in stages along the pipeline as offtakes for groups of villages were reached.

10.5 RETAINING THE EXISTING BOREHOLE SUPPLY TO ILINGE

In carrying out the comparison of augmentation options, it was assumed that the groundwater supply to Ilinge would no longer be used. However, this scheme, with an estimated capacity of 1,3 Mm^3/a, is a valuable asset. It is estimated (see Main Report, Section 3.9) that the development of a groundwater supply of similar capacity in the vicinity of Sada would cost at least R10 million. Therefore, it would be preferable to identify the causes of the operational difficulties that have been experienced with the scheme and, if possible, to remedy these.

If the existing Ilinge supply were retained, the additional capacity required for the Queenstown supply, shown in Table 5.1, would reduce to 2,85 Mm^3/a in 2005 and 3,8 Mm^3/a in 2020. If the Waterdown Pipeline were boosted to its full possible capacity and water were stored in Bonkolo Dam when the delivery of the pipeline exceeded requirements, an additional augmentation scheme, which would probably be a pipeline from Xonxa Dam, would not be required until the year 2017.

This approach would be considerably more economical than the immediate construction of a pipeline from Xonxa Dam. However, it would depend upon the availability of the 3,7 Mm^3/a portion of the yield of Waterdown, Oxkraal and Shiloh Dams that is currently unused, but is intended for irrigation, being made available for urban water supply. It appears, for the reasons given in Section 10.3, that the additional water is unlikely to be available for the urban supply. In that case, augmentation from Xonxa Dam will be required immediately and a decision on whether or not to retain the Ilinge boreholes will affect only the design capacity of the pipeline.

11. SUMMARY OF FINDINGS

The findings of this investigation of alternative potential augmentation schemes may be summarised as follows :

1. The preferred augmentation scheme is a pipeline from Xonxa Dam to Queenstown.

2. The required capacity of the pipeline and the date when it will need to be commissioned depend upon :

    - the extent to which the capacity of the existing pipeline from Waterdown Dam to Queenstown can be increased, and
    - the assured yield of the wellfield that currently supplies Ilinge and whether it is intended to maintain this supply or abandon it.

3. The indications from discussions held with the Department of Agriculture and the Chris Hani District Municipality during the course of this study were that the currently unutilised portion of the combined yields of Bushmanskrantz, Oxkraal and Shiloh Dams is likely to be required in the near future for the irrigation of lands to be developed for small scale farmers. Therefore, it is concluded that no additional water to the 5 Mm^3/a currently obtained through the Waterdown Pipeline will be available to Queenstown from Waterdown Dam. Consequently, a new pipeline to convey water from Xonxa Dam to Queenstown is required immediately.

4. The future of the Ilinge groundwater supply should be determined by those responsible for managing the water supplies. A decision on this needs to be made before the design of the Xonxa Pipeline augmentation scheme can be optimised.

12. RECOMMENDATIONS

As a result of the financial comparisons of alternative augmentation schemes described in this document, and on the basis of the conclusions drawn in Section 9, it is recommended that:

- the water supply to Queenstown should be augmented by means of a pipeline between Xonxa Dam and Queenstown
- the pipeline should be sized to deliver about 6,4 Mm^3/a of raw water to Queenstown to meet expected requirements to the year 2045
- the factors discussed in Section 10 of this document should be taken into account when carrying out the detailed design of the pipeline.

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ADDENDUM 6.1

Preliminary Comparison of Alternative Augmentation Schemes

ADDENDUM 6.1

PRELIMINARY COMPARISON OF ALTERNATIVE AUGMENTATION SCHEMES

1. INTRODUCTION

A preliminary financial comparison of possible augmentation schemes was carried out for screening purposes before the yields of the existing dams or the expected future water requirements had been finalised.

Additional sources of raw water to meet the predicted requirements of Queenstown to the year 2045 were assumed to be :

- Xonxa Dam with available yield at 1 in 50 year assurance of more than 10 Mm^3/a.
- A weir at Waklyn on the Black Kei River, some 21 km south of Queenstown and upstream of the Klaas Smits River confluence, with a maximum firm yield of 3,6 Mm^3/a. An abstraction capacity of 1,5 m^3/s would be required to obtain this yield (RWSFS). If storage volume of 1 Mm^3 is provided, the required abstraction capacity would be greatly reduced. The previous system analysis done by QRWSFS determined that an abstraction capacity of 0,5 m^3/s with 1 Mm^3 storage would provide a firm yield of 5,7 Mm^3 (QRWSFS). For the scheme where it is assumed that the existing Waterdown Pipeline to Queenstown would be abandoned, additional water would be released from Waterdown Dam into the river to be abstracted at the weir.
- A weir at Stitchel on the Black Kei River, some 17 km south of Queenstown, and downstream of the Klaas Smits River confluence, with a maximum firm yield of about 7 Mm^3/a. An abstraction capacity of 2 m^3/s would be required to obtain this yield (QRWSFS). As at the Waklyn site, a storage volume of 1 Mm^3 would provide an annual yield of 4,1 Mm^3 for a pumping capacity of 0,2 m^3/s (QRWSFS). Again, additional water will be released from Waterdown Dam into the river to be abstracted at the weir for the scheme where it is assumed that the Waterdown Pipeline will be abandoned.
- Raising of Waterdown Dam to increase its historical firm yield by 3,6 Mm^3/a (QRWSFS).

The assumed quantities of water that would be obtained from various sources in each of the combinations of possible augmentation schemes considered are shown in Table 1. The various options considered for the cases where the existing Waterdown Pipeline is assumed to continue to supply Sada and 5 Mm^3/a to Queenstown have been sized to increase the capacity of the water supply to Queenstown and adjacent rural villages from 6,35 Mm^3/a (Waterdown Pipeline and Bongolo Dam) to 9,18 Mm^3/a in 2005, followed by further augmentation of the capacity in 2020 to increase it to 10,65 Mm^3/a from 2021 onwards. As the predicted water requirements in 2045 are 10,45 Mm^3/a, the second augmentation will suffice to that date. For the cases where it has been assumed that the existing Waterdown Pipeline between Sada and Queenstown will be abandoned in 2005, the capacities of the schemes have been increased by an additional 5 Mm^3/a to compensate.

The assumed sizes of the components of the schemes will require further optimisation for the selected augmentation option. The schemes considered are described in the next section.

TABLE 1 (a) ASSUMED CONTRIBUTIONS OF RAW WATER SOURCES TO QUEENSTOWN WATER SUPPLY WITH THE EXISTING WATERDOWN PIPELINE CONTRIBUTING AN ADDITIONAL 5 Mm^3/a

Year	2005	2020	2045
		Flow (Mm^3/a)	
OPTION 1			
Waterdown	5.00	5.00	5.00
Bongola	1.35	1.35	1.35
Stitchel Weir Pipeline	16.95	2.83	2.83
Stitchel Weir Pipeline 2			1.27
OPTION 2			
Waterdown	5.00	5.00	5.00
Bongola	1.35	1.35	1.35
Xonxa Pipeline	1.95	2.83	2.83
Stitchel Weir Pipeline			1.27
OPTION 3			
Waterdown	5.00	5.00	5.00
Bongola	1.35	1.35	1.35
Stitchel Weir Pipeline	1.95	2.83	2.83
Xonxa Pipeline			1.27
OPTION 4			
Waterdown	5.00	5.00	5.00
Bongola	1.35	1.35	1.35
Xonxa Pipeline	1.95	2.83	4.10
OPTION 5			
Waterdown	5.00	5.00	5.00
Bongola	1.35	1.35	1.35
Waklyn Weir Pipeline	1.95	2.83	2.83
Waklyn Weir Pipeline 2			1.27
OPTION 6			
Bongola	1.35	1.35	1.35
Boosted Waterdown Pipeline	6.15	6.15	6.15
Xonxa Pipeline	0.80	1.68	2.95
OPTION 7			
Waterdown	5.00	5.00	5.00
Bongola	1.35	1.35	1.35
Xonxa Pipeline	1.95	2.83	2.83
Waklyn Weir Pipeline			1.27
OPTION 8			
Waterdown	5.00	5.00	5.00
Bongola	1.35	1.35	1.35
Xonxa Pipeline	1.95	2.83	2.83
Xonxa Pipeline 2			1.27
Total Scheme Capacity	**8.30**	**9.18**	**10.45**
Total Queenstown Requirement	7.52	8.51	9.90
Rural Req.	0.75	0.67	0.55
Total Scheme Requirements	**8.27**	**9.18**	**10.45**

TABLE 1 (b) ASSUMED CONTRIBUTIONS OF RAW WATER SOURCES TO QUEENSTOWN WATER SUPPLY WITH THE EXISTING WATERDOWN PIPELINE BETWEEN SADA AND QUEENSTOWN ABANDONED

Year	2005	2020	2045
		Flow (Mm^3/a)	
OPTION 9			
Bongola	1.35	1.35	1.35
Stitchel Weir Pipeline	6.95	7.83	7.83
Stitchel Weir Pipeline 2			1.27
OPTION 10			
Bongola	1.35	1.35	1.35
Xonxa Pipeline	6.95	7.83	7.83
Stitchel Weir Pipeline			1.27
OPTION 11			
Bongola	1.35	1.35	1.35
Stitchel Weir Pipeline	6.95	7.83	7.83
Xonxa Pipeline			1.27
OPTION 12			
Bongola	1.35	1.35	1.35
Xonxa Pipeline	6.95	7.83	90.10
OPTION 13			
Bongola	1.35	1.35	1.35
Waklyn Weir Pipeline	6.95	7.83	7.83
Waklyn Weir Pipeline 2			1.27
OPTION 14			
Bongola	1.35	1.35	1.35
new Waterdown Pipeline	6.95	7.83	9.10
OPTION 15			
Bongola	1.35	1.35	1.35
Xonxa Pipeline	6.95	7.83	7.83
Waklyn Weir Pipeline			1.27
OPTION 16			
Bongola	1.35	1.35	1.35
Xonxa Pipeline	6.95	7.83	7.83
Xonxa Pipeline 2			1.27
Total Scheme Capacity	**8.30**	**9.18**	**10.45**
Total Queenstown Requirement	7.52	8.51	9.90
Rural Req.	0.75	0.67	0.55
Total Scheme Requirements	**8.27**	**9.18**	**10.45**

2. AUGMENTATION SCHEMES

Sixteen different scheme development options, which are listed in Table 2, were assessed. These options represent each of the augmentation schemes that have been discussed in detail in the QRWSFS. The timing of the implementation of new schemes and the sizing of pipelines and pump stations has been adjusted to suit updated predictions of water requirements. (These estimates were subsequently further amended and used in the final comparison of augmentation schemes described in the Main Report.).

Pipelines and pump stations have been sized to deliver approximately 1,5 times the design average annual daily demand.

TABLE 2 SCHEME DEVELOPMENT OPTIONS INVESTIGATED AS PART OF THIS ANALYSIS

Option	Year	
	2005	2020
1	Construct Stitchel Weir and Pipeline (3.36 mm^3/a)	Construct 2nd Stitchel Pipeline (1.27 mm^3/a)
2	Construct Xonxa Pipeline (2.83 mm^3/a)	Construct Stitchel Weir and Pipeline (1.27 mm^3/a)
3	Construct Stitchel Weir and Pipeline (2.83 mm^3/a)	Construct Xonxa Pipeline (1.27 mm^3/a)
4	Construct Xonxa Pipeline (4.1 mm^3/a)	
5	Construct Waklyn Weir and Waklyn Pipeline (2.83 mm^3/a)	Construct 2nd Waklyn Pipeline (1.27 mm^3/a)
6	Boost existing Waterdown Pipeline (additional 1.15 mm^3/a) and construct Xonxa Pipeline (2.95 mm^3/a)	
7	Construct Xonxa Pipeline (2.83 mm^3/a)	Construct Waklyn Weir and Waklyn Pipeline (1.27 mm^3/a)
8	Construct Xonxa Pipeline (2.83 mm^3/a)	Construct Xonxa Pipeline (1.27 mm^3/a)
9	Construct Stitchel Weir and Pipeline (7.83 mm^3/a) and decommission Waterdown Pipeline	Construct 2nd Stitchel Pipeline (1.27 mm^3/a)
10	Construct Xonxa Pipeline (7.83 mm^3/a) and decommission Waterdown Pipeline	Construct Stitchel Weir and Pipeline (1.27 mm^3/a)
11	Construct Stitchel Weir and Pipeline (7.83 mm^3/a) and decommission Waterdown Pipeline	Construct Xonxa Pipeline (1.27 mm^3/a)
12	Construct Xonxa Pipeline (9.1 mm^3/a) and decommission Waterdown Pipeline	
13	Construct Waklyn Weir and Waklyn Pipeline (7.83 mm^3/a) and decommission Waterdown Pipeline	Construct 2nd Waklyn Pipeline (1.27 mm^3/a)
14	Raise Waterdown Dam and construct new pipeline (9.1 mm^3/a) and decomission Waterdown Pipeline	
15	Construct Xonxa Pipeline (7.83 mm^3/a) and decommission Waterdown Pipeline	Construct Waklyn Weir and Waklyn Pipeline (1.27 mm^3/a)
16	Construct Xonxa Pipeline (7.83 mm^3/a) and decommission Waterdown Pipeline	Construct Xonxa Pipeline (1.27 mm^3/a)

The following is a short description of the main scheme components: (Brief comments regarding water quality are also included).

2.1 Xonxa Pipeline

The Xonxa Pipeline is the proposed pipeline from Xonxa Dam to Queenstown. A 21.8 km pumping main carries the water over the high point of Nonesi's Nek, 10 km east of Queenstown, and delivers it into Berry Reservoir. The route requires two pump stations. The first pump station is sited below Xonxa Dam and the second pump station is situated at the head of Xonxa Valley. The design flow rate and pipeline diameters for the options considered are shown in Table 3.

In the QRWSFS it was concluded that the quality of water in Xonxa Dam is suitable for domestic use.

TABLE 3 : SIZING OF XONXA PIPELINE FOR VARIOUS OPTIONS

Option No.	Assumed Pipeline Diameter (mm)	Design Flow Rate (m^3/s)	Design Delivery (Mm^3/a)
2	300	0,14	2,83
3	200	0,06	1,27
4	400	0,20	4,10
6	300	0.14	2.95
7	300	0,14	2,83
8 Phase 1	300	0,14	2,83
8 Phase 2	200	0,06	1,27
10	500	0,37	7,83
11	200	0,06	1,27
12	600	0,43	9,10
15	500	0,37	7,83
16 Phase 1	500	0,37	7,83
16 Phase 2	200	0,06	1,27

2.2 Stitchel Weir and Stitchel Pipeline

As there is considerable water available in the Black Kei River (MAR of 51 Mm^3), a number of different weir sites on the river were investigated in the QRWSFS. The Stitchel Weir is one of two sites that were considered. The weir has a storage capacity of 1 Mm^3, a height from foundation to crest of 15.5 m and, because of the high silt load of the Klaas Smits River, large radial scour gates. The possibility of a dam at the Stitchel Weir site was also identified in the QRWSFS, but has not been considered in this analysis, as, for a low growth in water requirements, it was more expensive than a weir scheme.

The pipeline that is proposed to transfer the water to Queenstown consists of a 10.6 km pumping main and a diameter of 400 mm or 200 mm, depending on the capacity required. Two pump stations were assumed, as in the QRWSFS because of the high lift. A gravity main carries the water for the last 7.1 km to Berry Reservoir. The design flow rates for Stitchel Pipeline that have been costed are: as shown in Table 4. It needs to be confirmed by system analysis that these rates of abstraction in conjunction with a weir storage capacity of 1 Mm^3/a could provide the required yield at accepted assurance.

It should be noted that the water quality at the proposed Stitchel and Waklyn Weirs (see Section 2.3) is highly variable depending on the flow in the river. Especially during extended periods of low flow, high salinities may occur as a result of irrigation return flows in the Klaas Smits and Klipplaat Rivers as well as urban stormwater and sewage effluent in the Klaas Smits River. The QRWSFS found that the TDS at both sites may vary within a range of 200 to 700 mg/ℓ.

TABLE 4 SIZING OF STITCHEL PIPELINE FOR VARIOUS OPTIONS

Option No.	Assumed Pipeline Diameter (mm)	Design Flow Rate (m^3/s)	Design Delivery (Mm^3/a)
1 Phase 1	400	0,14	2,83
1 Phase 2	200	0,06	1,27
2	200	0,06	1,27
3	400	0,14	2,83
9 Phase 1	500	0,48	7,83
9 Phase 2	200	0,06	1,27
10	200	0,06	1,27
11	500	0,48	7,83

2.3 Waklyn Weir and Waklyn Pipeline

The Waklyn Weir is an alternative weir site to Stitchel Weir. The QRWSFS preferred the Waklyn Weir to the Stitchel Weir site as it lies upstream of the confluence of the Klaas Smits and Black Kei Rivers, thereby reducing the impact of sedimentation. Only one pump station is required at the start of the relatively short 7.8 km, 500 mm, diameter pumping main. A gravity main of 13.6 km is also required.

The design flow rates and pipeline diameters for the various options are as shown in Table 5. The pumping capacities are higher than for Stitchel Weir scheme as the yield available at Waklyn site is less than at Stitchel. As in the case of the Stitchel scheme, the adequacy of the assumed rates of abstraction requires confirmation by system analysis. A dam site at Waklyn was also identified in the QRWSFS, but has not been considered in this analysis as, for a low growth in water requirements, it was more expensive than a weir scheme.

TABLE 5 : SIZING OF WAKLYN PIPELINE FOR VARIOUS OPTIONS

Option No.	Assumed Pipeline Diameter (mm)	Design Flow Rate (m^3/s)	Design Delivery (Mm^3/a)
5 Phase 1	400	0,25	2,83
5 Phase 2	300	0,06	1,27
7	300	0,06	1,27
13 Phase 1	600	0,50	7,83
13 Phase 2	300	0,06	1,27
15	300	0,06	1,27

2.4 Boosting of the Existing Waterdown Pipeline

The capacity of the Waterdown Pipeline to Queenstown could be increased from the present 0,275 m^3/s to 0,33 m^3/s by installing an additional pump station. At present, a maximum of 5 Mm^3/a can be delivered to Queenstown if the supply to Sada is to be maintained at the level of peak summer demand (see Section 4 in the main body of this Appendix 6). Boosting the capacity to 0,33 m^3/s would allow an additional 1,15 m^3/a of water to be supplied to Queenstown at a peak factor of 1,5. This would bring the total quantity that could be supplied to Queenstown to 6,15 Mm^3/a. This, together with the 1,35 Mm^3/a available from Bongolo Dam, would not meet requirements to 2005 and an additional augmentation scheme would be required. The design combined capacity of the two pipelines between Xonxa Dam and Sada is 0,48 m^3/s (Stewart, Sviridov & Oliver, 1981). This is equivalent to 10 Mm^3/a at a peak factor of 1,5. As the estimated maximum requirement of Sada is 2,55 Mm^3/a (later increased to 3,0 Mm^3/a), the pipeline should be able to supply both Sada and 6,15 Mm^3/a to Queenstown, provided that a booster pump station is also provided on the branch line to Sada.

2.5 New Waterdown Pipeline

The possible new Waterdown to Queenstown pipeline would deliver water directly from Waterdown Dam to Berry Reservoir along the route of the existing pipeline. The pipeline would be some 48 km long with one booster pump and of 500 mm diameter. The pipeline has been designed for a flow rate of 0.43 m^3/s to deliver 9,0 Mm^3/a to Queenstown at a peak factor of 1.5. The quality of water supplied to Queenstown from the Waterdown Dam is well within the guidelines for domestic water supply (QRWSFS). Waterdown Dam would need to be raised, as discussed below, for this pipeline to be feasible.

2.6 Raising Waterdown Dam

Waterdown Dam was originally designed to be raised by 7.0 m, thus increasing the capacity from 21 Mm^3 to 59 Mm^3. This would make additional water available for supplying Queenstown or irrigators. The quality of the water in Waterdown Dam, after raising, may be slightly poorer than at present, depending on the degree of stratification in the larger reservoir.

The QRWSFS calculated that the increase in firm yield for the raising of the Waterdown Dam is 3.6 Mm^3/a.

3. DESIGN PARAMETERS

The same design parameters that were used for the QRWSFS were used for this study and are summarised below.

3.1 Pipelines

Only steel pipelines were considered.

Wall thicknesses were determined from the formula:

$$T = (P*D)/f_y$$

where
T = wall thickness in mm (subject to min = D/180 and max = 22 mm)
D = diameter of pipe
P = pressure(MPa); total pumping head- pumping mains, static head- gravity mains
f_y = yield stress of steel assumed to be 300 N/mm^2

The formula incorporates a normal allowance for overstress during surge conditions.

Longitudinal sections were obtained from the QRWSFS. These were determined at 100 or 200 m intervals and obtained from 1:10 000 orthophoto mapping for all the new pipelines (Xonxa, Stitchel and Waklyn) but off 1:50 000 topocadastral mapping for the existing and replacement Waterdown Pipeline.

A design flow rate of 1.5 times the AADD was used.

3.2 Pump Stations

The maximum single head was assumed to be 250 m. If the total head exceeded this two pumps were situated at convenient points. The same points that were selected for the QWSFS were adopted for this study.

The total pump head (H) was calculated as:

H = H static + H pump + H sec + H friction

where
H static = static head
H pump = 4 m per pump station
H sec = 1 m per km of rising main
H friction = friction loss computed by Hazen Williams formula with C = 125

4. COSTING

The various infrastructure components associated with each of the scheme development options were costed, based on 2003 rates. The following approach was used.

4.1 Pipelines

Updated costs for steel pipelines, based on a recent study for the City of Cape Town, were used, which include material and installation costs.

4.2 Pump Stations

Pump station costs were calculated based on the formula that was used in the QRWSFS and which originated in the Vaal Augmentation Planning Study (DWAF, 1994), after which they were escalated to 2003 prices:

Cost = A * H^8 * Q

where
A = 182 000
B = 0.65
Q = flow rate in m^3/s
H = total head pumped

The following allowances were assumed:

Civil cost	30	% of capital cost
Mechanical cost	50	% of capital cost
Pump and motor cost	60	% of mechanical cost
Electrical cost	20	% of capital cost
Maintenance cost (M&E)	4	% of mechanical & electrical cost
Maintenance cost (Civil)	0.25	% of civil cost
Operational costs	0.15	% of the total capital cost.

Energy costs were calculated as:

Basic:	R292.86/month
Power:	R62.9/kVA/month
Energy:	R 0.12/kWh

4.3 Weirs and Dams

Capital costs were based on the costs of the weirs and dams as per the QRWSFS (1995), escalated by 97% to 2003. Annual maintenance and operational costs were taken as 0.25% and 0.05% of the capital cost, respectively.

4.4 Results

The costs associated with each of the scheme development options are listed below: Note that all costs include Site Establishment, Contingencies and Professional Fees, but exclude VAT.

Option 1

2005	Stitchel Weir (1.0 Mm3)	R 45 million
	1st Stitchel Pipeline (400 mm diam)	R 22 million
2020	2nd Stitchel Pipeline (200 mm diam)	R 14 million
Total Capital cost		R 81 million
Operation and Maintenance Cost		R 0.3 mil/a
Pumping Cost (2045)		R 0.9 mil/a

Option 2

2005	Xonxa Pipeline (300 mm diam)	R 28 million
2020	Stitchel Weir (1.0 Mm^3)	R 45 million
	1st Stitchel Pipeline (200 mm diam)	R 14 million
Total Capital cost		R 87 million
Operation and Maintenance Cost		R 0.4 mil/a
Pumping Cost (2045)		R 1.5 mil/a

Option 3

2005	Stitchel Weir (1.0 Mm^3)	R 45 million
	1st Stitchel Pipeline (400 mm diam)	R 27 million
2020	Xonxa Pipeline (200 mm diam)	R 17 million
Total Capital cost		R 89 million
Operation and Maintenance Cost		R 0.4 mil/a

Option 4

2005	Xonxa Pipeline (400 mm diam)	R 34 million
Total Capital cost		R 34 million
Operation and Maintenance Cost		R 0.2 mil/a
Pumping Cost (2045)		R 1.3 mil/a

Option 5

2005	Waklyn Weir (1.0 Mm^3)	R 47 million
	1st Waklyn Pipeline (400 mm diam)	R 23 million
2020	2nd Waklyn Pipeline (300 mm diam)	R 17 million
Total Capital cost		R 87 million
Operation and Maintenance Cost		R 0.4 mil/a
Pumping Cost (2045)		R 1.2 mil/a

Option 6

2005	Boost Waterdown Pipeline	R 0.6 million
2005	Xonxa Pipeline (300 mm diam)	R 28 million
Total Capital cost		R 28.6 million
Operation and Maintenance Cost		R 0.2 million
Pumping Cost (2045)		R 1.36 million

Option 7

2005	Xonxa Pipeline (300 mm diam)	R 28 million
2020	Waklyn Weir (1.0 Mm^3)	R 47 million
	1st Waklyn Pipeline (300 mm diam)	R 17 million
Total Capital cost		R 92 million
Operation and Maintenance Cost		R 0.4 mil/a
Pumping Cost (2045)		R 1.3 mil/a

Option 8

2005	Xonxa Pipeline (300 mm diam)	R 28 million
2020	2nd Xonxa Pipeline (200 mm diam)	R 17 million
Total Capital cost		R 45 million
Operation and Maintenance Cost		R 0.3 mil/a
Pumping Cost (2045)		R 1.6 mil/a

Option 9

2005	Stitchel Weir (1.0 Mm^3)	R 45 million
	1st Stitchel Pipeline (500 mm diam)	R 35 million
2020	2nd Stitchel Pipeline (200 mm diam)	R 14 million
Total Capital cost		R 94 million
Operation and Maintenance Cost		R 0.5 mil/a
Pumping Cost (2045)		R 2.5 mil/a

Option 10

2005	Xonxa Pipeline (500 mm diam)	R 53 million
2020	Stitchel Weir (1.0 Mm^3)	R 45 million
	1st Stitchel Pipeline (400 mm diam)	R 14 million
Total Capital cost		R 112 million
Operation and Maintenance Cost		R 0.5 mil/a
Pumping Cost (2045)		R 3.2 mil/a

Option 11

2005	Stitchel Weir (1.0 Mm^3)	R 45 million
	1st Stitchel Pipeline (500 mm diam)	R 35 million
2020	Xonxa Pipeline (200 mm diam)	R 17 million
Total Capital cost		R 97 million
Operation and Maintenance Cost		R 0.5 mil/a
Pumping Cost (2045)		R 2.7 mil/a

Option 12

2005	Xonxa Pipeline (600 mm diam)	R 60 million
Total Capital cost		R 60 million
Operation and Maintenance Cost		R 0.4 mil/a
Pumping Cost (2045)		R 2.7 mil/a

Option 13

2005	Waklyn Weir (1.0 Mm^3)	R 47 million
	1st Waklyn Pipeline (600 mm diam)	R 35 million
2020	2nd Waklyn Pipeline (300 mm diam)	R 17 million
Total Capital cost		R 99 million
Operation and Maintenance Cost		R 0.4 mil/a
Pumping Cost (2045)		R 1.7 mil/a

Option 14

2005	Raise Waterdown Dam (7.0 m)	R 47 million
2005	New Waterdown Pipeline (500 mm. diam)	R 71 million
Total Capital cost		R 118 million
Operation and Maintenance Cost		R 0.4 mil/a
Pumping Cost (2045)		R 1.9 mil/a

Option 15

2005	Xonxa Pipeline (500 mm diam)	R 53 million
2020	Waklyn Weir (1.0 Mm^3)	R 47 million
	1st Waklyn Pipeline (300 mm diam)	R 17 million
Total Capital cost		R 117 million
Operation and Maintenance Cost		R 0.5 mil/a
Pumping Cost (2045)		R 3.0 mil/a

Option 16		
2005	Xonxa Pipeline (500 mm diam)	R 53 million
2020	2^{nd} Xonxa Pipeline (200 mm diam)	R 17 million
Total Capital cost		R 70 million
Operation and Maintenance Cost		R 0.4 mil/a
Pumping Cost (2045)		R 3.2 mil/a

4.5 Net Present Value

The relative costs of each of the different options were evaluated by comparing the Net Present Value of each scheme for different rates, as indicated in Table 6. (Note that residual values were not included in the NPV analysis.). Details of the calculations are given in Addendum 6.2.

TABLE 6 NET PRESENT VALUES (R MILLION)

	Option	3%	6%	9%
NPV (R mil.)	1	93.43	80.06	72.31
	2	94.91	67.57	52.12
	3	136.03	105.66	89.14
	4	57.44	46.49	40.65
	5	106.24	89.12	79.23
	6	51.14	40.57	35.10
	7	97.50	69.57	53.57
	8	67.90	50.60	41.30
	9	145.31	116.95	101.27
	10	160.98	117.57	93.47
	11	144.65	114.03	97.09
	12	119.08	94.24	80.86
	13	134.25	111.26	98.14
	14	160.45	135.33	120.34
	15	167.86	121.83	96.20
	16	133.95	100.60	82.66

The results of this preliminary analysis show that, for schemes where it is assumed that the existing Waterdown Pipeline will remain in operation indefinitely, Options 6 and 4 are the most economic for augmenting the water supply to Queenstown. The cost of Option 6 is less than that of Option 4 by between 11% and 14% for the range of discount rates considered. Option 8 is slightly more expensive than both Options 6 and 4, while the other options are significantly more expensive.

Option 6 entails boosting of the existing Waterdown Pipeline and constructing a single Xonxa Pipeline of 300 mm diameter in 2004. Option 8 entails the phased construction of two Xonxa Pipelines, while Option 4 is the construction of a single Xonxa Pipeline in place of the two smaller ones of Option 8.

For the options that entail the decommissioning of the existing Waterdown pipeline when the first scheme comes into operation, Option 12 proves to be the most economical for all the discount rates. This is a single 600 mm diameter Xonxa Pipeline constructed in 2004, that would supply the water requirements until 2045. At the discount rates of 6% and 9%, Option 16 (two single pipelines from Xonxa Dam to Queenstown) proves to be just slightly more expensive than the single Xonxa Pipeline. The other options are all significantly more expensive.

It should be noted that the pipeline diameters quoted in this document are not necessarily the optimum. Detailed design studies will be required to establish these.

ADDENDUM 6.2

Calculation of Net Present Values for Preliminary Comparison of Alternative Augmentation Schemes

OPTION 1

OPTION 1

COMPONENT CAPACITY	Stitchel Weir 1 Mm^3/a			Stitchel Weir Pipeline 400 mm diam				Stitchel Weir Pipeline 200 mm diam					FLOW SUPPLIED (Mm^3/a)						FLOW REQUIRED (Mm^3/a)		
	Construct Weir	Maintenance Cost	Operation Cost	Construct Pipeline/ Pump	Maintenance Cost	Operation Cost	Pumping Cost	Construct Pipeline/ Pump	Maintenance Cost	Operation Cost	Pumping Cost	TOTAL CASH FLOW	Waterdown Pipeline (Existing) Queenstown Allocation	Bongola	Stitchel Weir Pipeline	Stitchel Weir Pipeline 2	**Total Queenstown Supply**	**Total Queenstown Demand**	Total Queensstown Requirement	Rural Req.	Sada
YEAR																			7.29	0.740	2.20
2003																			7.41	0.746	2.21
2004	44,604,408			22,357,958								66,962,366	5.00						7.52	0.749	2.21
2005		111,511	22,302		87,759	28,377	349,386					599,335	5.00	1.35	1.96		**8.31**	**8.31**	7.57	0.743	2.22
2006		111,511	22,302		87,759	28,377	364,972					614,922	5.00	1.35	2.03		**8.38**	**8.38**	7.64	0.739	2.23
2007		111,511	22,302		87,759	28,377	380,725					630,674	5.00	1.35	2.09		**8.44**	**8.44**	7.70	0.735	2.23
2008		111,511	22,302		87,759	28,377	396,646					646,595	5.00	1.35	2.15		**8.50**	**8.50**	7.77	0.731	2.24
2009		111,511	22,302		87,759	28,377	412,737					662,687	5.00	1.35	2.21		**8.56**	**8.56**	7.84	0.727	2.25
2010		111,511	22,302		87,759	28,377	429,001					678,950	5.00	1.35	2.28		**8.63**	**8.63**	7.91	0.723	2.25
2011		111,511	22,302		87,759	28,377	445,438					695,387	5.00	1.35	2.34		**8.69**	**8.69**	7.97	0.719	2.26
2012		111,511	22,302		87,759	28,377	462,051					712,000	5.00	1.35	2.41		**8.76**	**8.76**	8.04	0.715	2.27
2013		111,511	22,302		87,759	28,377	478,841					728,791	5.00	1.35	2.47		**8.82**	**8.82**	8.11	0.711	2.27
2014		111,511	22,302		87,759	28,377	495,812					745,761	5.00	1.35	2.54		**8.89**	**8.89**	8.18	0.707	2.28
2015		111,511	22,302		87,759	28,377	512,964					762,913	5.00	1.35	2.61		**8.96**	**8.96**	8.26	0.704	2.29
2016		111,511	22,302		87,759	28,377	530,300					780,249	5.00	1.35	2.65		**9.00**	**9.00**	8.31	0.698	2.29
2017		111,511	22,302		87,759	28,377	547,821					797,770	5.00	1.35	2.70		**9.05**	**9.05**	8.36	0.692	2.30
2018		111,511	22,302		87,759	28,377	565,530					815,479	5.00	1.35	2.74		**9.09**	**9.09**	8.41	0.686	2.31
2019		111,511	22,302		87,759	28,377	583,429					833,378	5.00	1.35	2.79		**9.14**	**9.14**	8.46	0.680	2.31
2020		111,511	22,302		87,759	28,377	601,520	14,373,497				15,224,966	5.00	1.35	2.83		**9.18**	**9.18**	8.51	0.674	2.31
2021		111,511	22,302		87,759	28,377	273,465		51,213	18,086	273,465	866,179	5.00	1.35	2.83	0.05	**9.23**	**9.23**	8.56	0.668	2.31
2022		111,511	22,302		87,759	28,377	281,619		51,213	18,086	281,619	882,487	5.00	1.35	2.83	0.10	**9.28**	**9.28**	8.61	0.663	2.31
2023		111,511	22,302		87,759	28,377	289,861		51,213	18,086	289,861	898,970	5.00	1.35	2.83	0.14	**9.32**	**9.32**	8.67	0.657	2.31
2024		111,511	22,302		87,759	28,377	298,191		51,213	18,086	298,191	915,630	5.00	1.35	2.83	0.19	**9.37**	**9.37**	8.72	0.652	2.31
2025		111,511	22,302		87,759	28,377	306,610		51,213	18,086	306,610	932,469	5.00	1.35	2.83	0.24	**9.42**	**9.42**	8.77	0.646	2.31
2026		111,511	22,302		87,759	28,377	315,120		51,213	18,086	315,120	949,488	5.00	1.35	2.83	0.29	**9.47**	**9.47**	8.83	0.641	2.31
2027		111,511	22,302		87,759	28,377	323,721		51,213	18,086	323,721	966,691	5.00	1.35	2.83	0.34	**9.52**	**9.52**	8.88	0.635	2.31
2028		111,511	22,302		87,759	28,377	332,415		51,213	18,086	332,415	984,078	5.00	1.35	2.83	0.38	**9.56**	**9.56**	8.93	0.630	2.31
2029		111,511	22,302		87,759	28,377	341,202		51,213	18,086	341,202	1,001,652	5.00	1.35	2.83	0.43	**9.61**	**9.61**	8.99	0.624	2.31
2030		111,511	22,302		87,759	28,377	350,083		51,213	18,086	350,083	1,019,415	5.00	1.35	2.83	0.48	**9.66**	**9.66**	9.04	0.619	2.31
2031		111,511	22,302		87,759	28,377	359,061		51,213	18,086	359,061	1,037,369	5.00	1.35	2.83	0.53	**9.71**	**9.71**	9.10	0.614	2.31
2032		111,511	22,302		87,759	28,377	368,134		51,213	18,086	368,134	1,055,516	5.00	1.35	2.83	0.58	**9.76**	**9.76**	9.15	0.609	2.31
2033		111,511	22,302		87,759	28,377	377,305		51,213	18,086	377,305	1,073,859	5.00	1.35	2.83	0.63	**9.81**	**9.81**	9.21	0.603	2.31
2034		111,511	22,302		87,759	28,377	386,575		51,213	18,086	386,575	1,092,399	5.00	1.35	2.83	0.68	**9.86**	**9.86**	9.27	0.598	2.31
2035		111,511	22,302		87,759	28,377	395,945		51,213	18,086	395,945	1,111,138	5.00	1.35	2.83	0.74	**9.92**	**9.92**	9.32	0.593	2.31
2036		111,511	22,302		87,759	28,377	405,416		51,213	18,086	405,416	1,130,080	5.00	1.35	2.83	0.79	**9.97**	**9.97**	9.38	0.588	2.31
2037		111,511	22,302		87,759	28,377	414,989		51,213	18,086	414,989	1,149,225	5.00	1.35	2.83	0.84	**10.02**	**10.02**	9.44	0.583	2.31
2038		111,511	22,302		87,759	28,377	424,664		51,213	18,086	424,664	1,168,577	5.00	1.35	2.83	0.89	**10.07**	**10.07**	9.49	0.578	2.31
2039		111,511	22,302		87,759	28,377	434,445		51,213	18,086	434,445	1,188,138	5.00	1.35	2.83	0.95	**10.13**	**10.13**	9.55	0.573	2.31
2040		111,511	22,302		87,759	28,377	444,330		51,213	18,086	444,330	1,207,909	5.00	1.35	2.83	1.00	**10.18**	**10.18**	9.61	0.568	2.31
2041		111,511	22,302		87,759	28,377	454,323		51,213	18,086	454,323	1,227,893	5.00	1.35	2.83	1.05	**10.23**	**10.23**	9.67	0.564	2.31
2042		111,511	22,302		87,759	28,377	464,423		51,213	18,086	464,423	1,248,094	5.00	1.35	2.83	1.11	**10.29**	**10.29**	9.73	0.559	2.31
2043		111,511	22,302		87,759	28,377	474,632		51,213	18,086	474,632	1,268,512	5.00	1.35	2.83	1.16	**10.34**	**10.34**	9.79	0.554	2.31
2044		111,511	22,302		87,759	28,377	484,951		51,213	18,086	484,951	1,289,151	5.00	1.35	2.83	1.22	**10.40**	**10.40**	9.85	0.549	2.31
2045		111,511	22,302		87,759	28,377	495,382		51,213	18,086	377,025	1,191,655	5.00	1.35	2.83	1.27	**10.45**	**10.45**	9.91	0.545	2.31

NP Cost at 3%	93,426,221
NP Cost at 6%	80,057,781
NP Cost at 9%	72,308,911

Capital Cost :	81,335,863
Operation + Maintenance	319,248
Pumping Costs	872,407

OPTION 2

OPTION 2

COMPONENT CAPACITY	Xonxa Pipeline 300 mm diam				Stitchel Weir $1 Mm^3/a$			Stitchel Weir Pipeline 200 mm diam					FLOW (Mm^3/a)						FLOW REQUIRED (Mm^3/a)		
YEAR	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	Construct Weir	Maintenance Cost	Operation Cost	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	TOTAL CASH FLOW	Waterdown Pipeline (Existing)	Bongola	Xonxa Pipeline	Stitchel Weir Pipeline 2	Total Queenstown Supply	Total Queenstown Demand	Total Queensstown Requirement	Rural Req.	Sada
																			7.29	0.740	2.20
2003																			7.41	0.746	2.21
2004	27,720,536											27,720,536	5.0						7.52	0.749	2.21
2005		116,120	35,308	788,715								940,143	5.0	1.35	1.96		8.31	8.31	7.57	0.743	2.22
2006		127,498	41,883	813,564								982,945	5.0	1.35	2.03		8.38	8.38	7.64	0.739	2.23
2007		127,498	41,883	838,652								1,008,033	5.0	1.35	2.09		8.44	8.44	7.70	0.735	2.23
2008		127,498	41,883	863,980								1,033,361	5.0	1.35	2.15		8.50	8.50	7.77	0.731	2.24
2009		127,498	41,883	889,552								1,058,933	5.0	1.35	2.21		8.56	8.56	7.84	0.727	2.25
2010		127,498	41,883	915,368								1,084,749	5.0	1.35	2.28		8.63	8.63	7.91	0.723	2.25
2011		127,498	41,883	941,432								1,110,813	5.0	1.35	2.34		8.69	8.69	7.97	0.719	2.26
2012		127,498	41,883	967,744								1,137,125	5.0	1.35	2.41		8.76	8.76	8.04	0.715	2.27
2013		127,498	41,883	994,307								1,163,688	5.0	1.35	2.47		8.82	8.82	8.11	0.711	2.27
2014		127,498	41,883	1,021,122								1,190,503	5.0	1.35	2.54		8.89	8.89	8.18	0.707	2.28
2015		127,498	41,883	1,048,193								1,217,574	5.0	1.35	2.61		8.96	8.96	8.26	0.704	2.29
2016		127,498	41,883	1,066,022								1,235,403	5.0	1.35	2.65		9.00	9.00	8.31	0.698	2.29
2017		127,498	41,883	1,083,995								1,253,376	5.0	1.35	2.70		9.05	9.05	8.36	0.692	2.30
2018		127,498	41,883	1,102,112								1,271,493	5.0	1.35	2.74		9.09	9.09	8.41	0.686	2.31
2019		127,498	41,883	1,120,373	44,604,408							45,894,162	5.0	1.35	2.79		9.14	9.14	8.46	0.680	2.31
2020		127,498	41,883	1,138,781		111,511	22,302	14,373,497				15,815,472	5.0	1.35	2.83		9.18	9.18	8.51	0.674	2.31
2021		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	15,039	1,524,476	5.0	1.35	2.83	0.05	9.23	9.23	8.56	0.668	2.31
2022		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	28,831	1,538,268	5.0	1.35	2.83	0.10	9.28	9.28	8.61	0.663	2.31
2023		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	42,732	1,552,169	5.0	1.35	2.83	0.14	9.32	9.32	8.67	0.657	2.31
2024		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	56,742	1,566,179	5.0	1.35	2.83	0.19	9.37	9.37	8.72	0.652	2.31
2025		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	70,862	1,580,299	5.0	1.35	2.83	0.24	9.42	9.42	8.77	0.646	2.31
2026		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	85,092	1,594,529	5.0	1.35	2.83	0.29	9.47	9.47	8.83	0.641	2.31
2027		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	99,432	1,608,869	5.0	1.35	2.83	0.34	9.52	9.52	8.88	0.635	2.31
2028		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	113,883	1,623,321	5.0	1.35	2.83	0.38	9.56	9.56	8.93	0.630	2.31
2029		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	128,446	1,637,883	5.0	1.35	2.83	0.43	9.61	9.61	8.99	0.624	2.31
2030		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	143,121	1,652,558	5.0	1.35	2.83	0.48	9.66	9.66	9.04	0.619	2.31
2031		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	157,908	1,667,346	5.0	1.35	2.83	0.53	9.71	9.71	9.10	0.614	2.31
2032		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	172,809	1,682,246	5.0	1.35	2.83	0.58	9.76	9.76	9.15	0.609	2.31
2033		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	187,823	1,697,260	5.0	1.35	2.83	0.63	9.81	9.81	9.21	0.603	2.31
2034		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	202,950	1,712,388	5.0	1.35	2.83	0.68	9.86	9.86	9.27	0.598	2.31
2035		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	218,193	1,727,630	5.0	1.35	2.83	0.74	9.92	9.92	9.32	0.593	2.31
2036		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	233,550	1,742,987	5.0	1.35	2.83	0.79	9.97	9.97	9.38	0.588	2.31
2037		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	249,023	1,758,460	5.0	1.35	2.83	0.84	10.02	10.02	9.44	0.583	2.31
2038		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	264,611	1,774,048	5.0	1.35	2.83	0.89	10.07	10.07	9.49	0.578	2.31
2039		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	280,316	1,789,754	5.0	1.35	2.83	0.95	10.13	10.13	9.55	0.573	2.31
2040		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	296,139	1,805,576	5.0	1.35	2.83	1.00	10.18	10.18	9.61	0.568	2.31
2041		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	312,079	1,821,516	5.0	1.35	2.83	1.05	10.23	10.23	9.67	0.564	2.31
2042		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	328,137	1,837,574	5.0	1.35	2.83	1.11	10.29	10.29	9.73	0.559	2.31
2043		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	344,313	1,853,751	5.0	1.35	2.83	1.16	10.34	10.34	9.79	0.554	2.31
2044		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	360,609	1,870,047	5.0	1.35	2.83	1.22	10.40	10.40	9.85	0.549	2.31
2045		127,498	41,883	1,136,944		111,511	22,302		51,213	18,086	377,025	1,886,462	5.0	1.35	2.83	1.27	10.45	10.45	9.91	0.545	2.31

NP Cost at 3%	94,908,215
NP Cost at 6%	67,570,380
NP Cost at 9%	52,117,689

Capital Cost :	86,698,441
Operation + Maintenance	372,493
Pumping Costs	1,513,969

OPTION 3

COMPONENT	Stitchel Weir (OPTION 3)			Stitchel Weir Pipeline				Xonxa Pipeline					FLOW (Mm3/a)						FLOW REQUIRED (Mm3/a)		
CAPACITY	1Mm^3/a			400 mm diam				200mm diam													
YEAR	Construct Weir	Maintenance Cost	Operation Cost	Construct Pipeline/ Pump	Maintenance Cost	Operation Cost	Pumping Cost	Construct Pipeline/ Pump	Maintenanc Cost	Operation Cost	Pumping Cost	TOTAL CASH FLOW	Waterdown Pipeline (Existing)	Bongola	Stitchel Weir Pipeline	Xonxa Pipeline	Total Queenstown Supply	Total Queenstown Demand	Total Queenstown Requirement	Rural Req.	Sada
																			7.29	0.740	2.20
2003	44,604,408											**44,604,408**							7.41	0.746	2.21
2004		111511.02	22302	27,293,070								**27,426,883**	5.0						7.52	0.749	2.21
2005		111,511	22,302		187,336	34,756	1,575,296					**1,931,201**	5.0	1.35	1.96		**8.31**	**8.31**	7.57	0.743	2.22
2006		111,511	22,302		187,336	34,756	1,624,926					**1,980,831**	5.0	1.35	2.03		**8.38**	**8.38**	7.64	0.739	2.23
2007		111,511	22,302		187,336	34,756	1,675,034					**2,030,939**	5.0	1.35	2.09		**8.44**	**8.44**	7.70	0.735	2.23
2008		111,511	22,302		187,336	34,756	1,725,623					**2,081,528**	5.0	1.35	2.15		**8.50**	**8.50**	7.77	0.731	2.24
2009		111,511	22,302		187,336	34,756	1,776,697					**2,132,602**	5.0	1.35	2.21		**8.56**	**8.56**	7.84	0.727	2.25
2010		111,511	22,302		187,336	34,756	1,828,259					**2,184,165**	5.0	1.35	2.28		**8.63**	**8.63**	7.91	0.723	2.25
2011		111,511	22,302		187,336	34,756	1,880,315					**2,236,220**	5.0	1.35	2.34		**8.69**	**8.69**	7.97	0.719	2.26
2012		111,511	22,302		187,336	34,756	1,932,868					**2,288,773**	5.0	1.35	2.41		**8.76**	**8.76**	8.04	0.715	2.27
2013		111,511	22,302		187,336	34,756	1,985,922					**2,341,827**	5.0	1.35	2.47		**8.82**	**8.82**	8.11	0.711	2.27
2014		111,511	22,302		187,336	34,756	2,039,481					**2,395,387**	5.0	1.35	2.54		**8.89**	**8.89**	8.18	0.707	2.28
2015		111,511	22,302		187,336	34,756	2,093,550					**2,449,455**	5.0	1.35	2.61		**8.96**	**8.96**	8.26	0.704	2.29
2016		111,511	22,302		187,336	34,756	2,129,159					**2,485,064**	5.0	1.35	2.65		**9.00**	**9.00**	8.31	0.698	2.29
2017		111,511	22,302		187,336	34,756	2,165,056					**2,520,961**	5.0	1.35	2.70		**9.05**	**9.05**	8.36	0.692	2.30
2018		111,511	22,302		187,336	34,756	2,201,240					**2,557,146**	5.0	1.35	2.74		**9.09**	**9.09**	8.41	0.686	2.31
2019		111,511	22,302		187,336	34,756	2,237,715					**2,593,620**	5.0	1.35	2.79		**9.14**	**9.14**	8.46	0.680	2.31
2020		111,511	22,302		187,336	34,756	2,274,480	17,218,061				**19,848,446**	5.0	1.35	2.83		**9.18**	**9.18**	8.51	0.674	2.31
2021		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	18,451	**2,730,831**	5.0	1.35	2.83	0.05	**9.23**	**9.23**	8.56	0.668	2.31
2022		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	35,373	**2,747,753**	5.0	1.35	2.83	0.10	**9.28**	**9.28**	8.61	0.663	2.31
2023		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	52,429	**2,764,808**	5.0	1.35	2.83	0.14	**9.32**	**9.32**	8.67	0.657	2.31
2024		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	69,618	**2,781,997**	5.0	1.35	2.83	0.19	**9.37**	**9.37**	8.72	0.652	2.31
2025		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	86,942	**2,799,321**	5.0	1.35	2.83	0.24	**9.42**	**9.42**	8.77	0.646	2.31
2026		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	104,401	**2,816,780**	5.0	1.35	2.83	0.29	**9.47**	**9.47**	8.83	0.641	2.31
2027		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	121,996	**2,834,375**	5.0	1.35	2.83	0.34	**9.52**	**9.52**	8.88	0.635	2.31
2028		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	139,726	**2,852,106**	5.0	1.35	2.83	0.38	**9.56**	**9.56**	8.93	0.630	2.31
2029		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	157,594	**2,869,973**	5.0	1.35	2.83	0.43	**9.61**	**9.61**	8.99	0.624	2.31
2030		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	175,599	**2,887,978**	5.0	1.35	2.83	0.48	**9.66**	**9.66**	9.04	0.619	2.31
2031		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	193,742	**2,906,121**	5.0	1.35	2.83	0.53	**9.71**	**9.71**	9.10	0.614	2.31
2032		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	212,024	**2,924,403**	5.0	1.35	2.83	0.58	**9.76**	**9.76**	9.15	0.609	2.31
2033		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	230,445	**2,942,824**	5.0	1.35	2.83	0.63	**9.81**	**9.81**	9.21	0.603	2.31
2034		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	249,005	**2,961,384**	5.0	1.35	2.83	0.68	**9.86**	**9.86**	9.27	0.598	2.31
2035		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	267,706	**2,980,086**	5.0	1.35	2.83	0.74	**9.92**	**9.92**	9.32	0.593	2.31
2036		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	286,548	**2,998,928**	5.0	1.35	2.83	0.79	**9.97**	**9.97**	9.38	0.588	2.31
2037		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	305,532	**3,017,912**	5.0	1.35	2.83	0.84	**10.02**	**10.02**	9.44	0.583	2.31
2038		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	324,659	**3,037,038**	5.0	1.35	2.83	0.89	**10.07**	**10.07**	9.49	0.578	2.31
2039		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	343,928	**3,056,307**	5.0	1.35	2.83	0.95	**10.13**	**10.13**	9.55	0.573	2.31
2040		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	363,340	**3,075,720**	5.0	1.35	2.83	1.00	**10.18**	**10.18**	9.61	0.568	2.31
2041		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	382,898	**3,095,277**	5.0	1.35	2.83	1.05	**10.23**	**10.23**	9.67	0.564	2.31
2042		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	402,600	**3,114,979**	5.0	1.35	2.83	1.11	**10.29**	**10.29**	9.73	0.559	2.31
2043		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	422,447	**3,134,826**	5.0	1.35	2.83	1.16	**10.34**	**10.34**	9.79	0.554	2.31
2044		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	442,441	**3,154,820**	5.0	1.35	2.83	1.22	**10.40**	**10.40**	9.85	0.549	2.31
2045		111,511	22,302		187,336	34,756	2,274,480		60,261	21,733	462,582	**3,174,961**	5.00	1.35	2.83	1.27	**10.45**	**10.45**	9.91	0.545	2.31

NP Cost at 3%	136,027,678
NP Cost at 6%	105,656,833
NP Cost at 9%	89,141,919

Capital Cost :	89,115,539
Operation + Maintenance	437,899
Pumping Costs	2,737,062

OPTION 4

	OPTION 4												
COMPONENT	Xonxa Pipeline					FLOW (Mm^3/a)					FLOW REQUIRED (Mm^3/a)		
CAPACITY	400 mm diam												
	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	**TOTAL CASH FLOW**	Waterdown Pipeline (Existing)	Bongola	Xonxa Pipeline	**Total Queenstown Supply**	**Total Queenstown Demand**	Total Queenstown Requirement	Rural Req.	Sada
YEAR											7.29	0.740	2.20
2003											7.41	0.746	2.21
2004	33,643,687				**33,643,687**	5.0					7.45	0.749	2.21
2005		144,276	42,964	619,459	**806,699**	5.0	1.35	1.91	**8.26**	**8.26**	7.52	0.743	2.22
2006		144,276	42,964	639,384	**826,624**	5.0	1.35	1.97	**8.32**	**8.32**	7.58	0.739	2.23
2007		144,276	42,964	659,500	**846,740**	5.0	1.35	2.03	**8.38**	**8.38**	7.65	0.735	2.23
2008		144,276	42,964	679,809	**867,049**	5.0	1.35	2.09	**8.44**	**8.44**	7.71	0.731	2.24
2009		144,276	42,964	700,314	**887,554**	5.0	1.35	2.16	**8.51**	**8.51**	7.78	0.727	2.25
2010		144,276	42,964	721,015	**908,255**	5.0	1.35	2.22	**8.57**	**8.57**	7.85	0.723	2.25
2011		144,276	42,964	741,914	**929,154**	5.0	1.35	2.29	**8.64**	**8.64**	7.92	0.719	2.26
2012		144,276	42,964	763,012	**950,252**	5.0	1.35	2.35	**8.70**	**8.70**	7.99	0.715	2.27
2013		144,276	42,964	784,312	**971,552**	5.0	1.35	2.42	**8.77**	**8.77**	8.05	0.711	2.27
2014		144,276	42,964	805,815	**993,055**	5.0	1.35	2.48	**8.83**	**8.83**	8.12	0.707	2.28
2015		144,276	42,964	820,665	**1,007,905**	5.0	1.35	2.53	**8.88**	**8.88**	8.17	0.704	2.29
2016		144,276	42,964	834,911	**1,022,151**	5.0	1.35	2.57	**8.92**	**8.92**	8.22	0.698	2.29
2017		144,276	42,964	849,273	**1,036,513**	5.0	1.35	2.62	**8.97**	**8.97**	8.27	0.692	2.30
2018		144,276	42,964	863,750	**1,050,990**	5.0	1.35	2.66	**9.01**	**9.01**	8.32	0.686	2.31
2019		144,276	42,964	878,344	**1,065,584**	5.0	1.35	2.71	**9.06**	**9.06**	8.38	0.680	2.31
2020		144,276	42,964	893,054	**1,080,294**	5.0	1.35	2.75	**9.10**	**9.10**	8.43	0.674	2.31
2021		144,276	42,964	907,881	**1,095,121**	5.0	1.35	2.80	**9.15**	**9.15**	8.48	0.668	2.31
2022		144,276	42,964	922,826	**1,110,066**	5.0	1.35	2.84	**9.19**	**9.19**	8.53	0.663	2.31
2023		144,276	42,964	937,889	**1,125,129**	5.0	1.35	2.89	**9.24**	**9.24**	8.58	0.657	2.31
2024		144,276	42,964	953,071	**1,140,311**	5.0	1.35	2.94	**9.29**	**9.29**	8.63	0.652	2.31
2025		144,276	42,964	968,372	**1,155,612**	5.0	1.35	2.98	**9.33**	**9.33**	8.69	0.646	2.31
2026		144,276	42,964	983,792	**1,171,032**	5.0	1.35	3.03	**9.38**	**9.38**	8.74	0.641	2.31
2027		144,276	42,964	999,332	**1,186,572**	5.0	1.35	3.08	**9.43**	**9.43**	8.79	0.635	2.31
2028		144,276	42,964	1,014,993	**1,202,233**	5.0	1.35	3.13	**9.48**	**9.48**	8.85	0.630	2.31
2029		144,276	42,964	1,030,775	**1,218,015**	5.0	1.35	3.18	**9.53**	**9.53**	8.90	0.624	2.31
2030		144,276	42,964	1,046,679	**1,233,919**	5.0	1.35	3.22	**9.57**	**9.57**	8.95	0.619	2.31
2031		144,276	42,964	1,062,705	**1,249,945**	5.0	1.35	3.27	**9.62**	**9.62**	9.01	0.614	2.31
2032		144,276	42,964	1,078,854	**1,266,094**	5.0	1.35	3.32	**9.67**	**9.67**	9.06	0.609	2.31
2033		144,276	42,964	1,095,125	**1,282,365**	5.0	1.35	3.37	**9.72**	**9.72**	9.12	0.603	2.31
2034		144,276	42,964	1,111,521	**1,298,761**	5.0	1.35	3.42	**9.77**	**9.77**	9.18	0.598	2.31
2035		144,276	42,964	1,128,041	**1,315,281**	5.0	1.35	3.47	**9.82**	**9.82**	9.23	0.593	2.31
2036		144,276	42,964	1,144,686	**1,331,926**	5.0	1.35	3.53	**9.88**	**9.88**	9.29	0.588	2.31
2037		144,276	42,964	1,161,456	**1,348,696**	5.0	1.35	3.58	**9.93**	**9.93**	9.34	0.583	2.31
2038		144,276	42,964	1,178,352	**1,365,592**	5.0	1.35	3.63	**9.98**	**9.98**	9.40	0.578	2.31
2039		144,276	42,964	1,195,375	**1,382,615**	5.0	1.35	3.68	**10.03**	**10.03**	9.46	0.573	2.31
2040		144,276	42,964	1,212,525	**1,399,765**	5.0	1.35	3.73	**10.08**	**10.08**	9.52	0.568	2.31
2041		144,276	42,964	1,229,803	**1,417,043**	5.0	1.35	3.79	**10.14**	**10.14**	9.57	0.564	2.31
2042		144,276	42,964	1,247,209	**1,434,449**	5.0	1.35	3.84	**10.19**	**10.19**	9.63	0.559	2.31
2043		144,276	42,964	1,264,743	**1,451,983**	5.0	1.35	3.90	**10.25**	**10.25**	9.69	0.554	2.31
2044		144,276	42,964	1,282,408	**1,469,648**	5.0	1.35	3.95	**10.30**	**10.30**	9.75	0.549	2.31
2045		144,276	42,964	1,331,858	**1,519,098**	5.0	1.35	4.10	**10.45**	**10.45**	9.91	0.545	2.31

NP Cost at 3%	57,436,679
NP Cost at 6%	46,488,145
NP Cost at 9%	40,645,219

Capital Cost :	33,643,687
Operation + Maintenance	187,240
Pumping Costs	1,331,858

OPTION 5

OPTION 5

COMPONENT	Waklyn Weir			Waklyn Pipeline				Waklyn Pipeline					FLOW (Mm³/a)						FLOW REQUIRED (Mm³/a)		
CAPACITY	1Mm³/a			400 mm diam				300mm diam													
	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	TOTAL CASH FLOW	Waterdown Pipeline (Existing)	Bongola	Waklyn Weir Pipeline	Waklyn Weir Pipeline	Total Queenstown Supply	Total Queenstown Demand	Total Queenstown Requirement	Rural Req.	Sada
2003																			7.41	0.746	2.21
2004	47,005,250			22,827,393								**69,832,643**	5.0	1.35					7.52	0.749	2.21
2005		117,513	23,503		116,293	29,984	0					**287,293**	5.0	1.35	1.96		**8.31**	**8.31**	7.57	0.743	2.22
2006		117,513	23,503		116,293	29,984	690,455					**977,747**	5.0	1.35	2.03		**8.38**	**8.38**	7.64	0.739	2.23
2007		117,513	23,503		116,293	29,984	712,208					**999,500**	5.0	1.35	2.09		**8.44**	**8.44**	7.70	0.735	2.23
2008		117,513	23,503		116,293	29,984	734,170					**1,021,463**	5.0	1.35	2.15		**8.50**	**8.50**	7.77	0.731	2.24
2009		117,513	23,503		116,293	29,984	756,343					**1,043,636**	5.0	1.35	2.21		**8.56**	**8.56**	7.84	0.727	2.25
2010		117,513	23,503		116,293	29,984	778,729					**1,066,022**	5.0	1.35	2.28		**8.63**	**8.63**	7.91	0.723	2.25
2011		117,513	23,503		116,293	29,984	801,329					**1,088,622**	5.0	1.35	2.34		**8.69**	**8.69**	7.97	0.719	2.26
2012		117,513	23,503		116,293	29,984	824,145					**1,111,438**	5.0	1.35	2.41		**8.76**	**8.76**	8.04	0.715	2.27
2013		117,513	23,503		116,293	29,984	847,179					**1,134,472**	5.0	1.35	2.47		**8.82**	**8.82**	8.11	0.711	2.27
2014		117,513	23,503		116,293	29,984	870,433					**1,157,726**	5.0	1.35	2.54		**8.89**	**8.89**	8.18	0.707	2.28
2015		117,513	23,503		116,293	29,984	893,908					**1,181,201**	5.0	1.35	2.61		**8.96**	**8.96**	8.26	0.704	2.29
2016		117,513	23,503		116,293	29,984	917,606					**1,204,899**	5.0	1.35	2.65		**9.00**	**9.00**	8.31	0.698	2.29
2017		117,513	23,503		116,293	29,984	933,214					**1,220,507**	5.0	1.35	2.70		**9.05**	**9.05**	8.36	0.692	2.30
2018		117,513	23,503		116,293	29,984	948,947					**1,236,240**	5.0	1.35	2.74		**9.09**	**9.09**	8.41	0.686	2.31
2019		117,513	23,503		116,293	29,984	980,794	17,028,093				**18,296,180**	5.0	1.35	2.79		**9.14**	**9.14**	8.46	0.680	2.31
2020		117,513	23,503		116,293	29,984	980,794		46,019	21,488	0	**1,335,594**	5.0	1.35	2.83		**9.18**	**9.18**	8.51	0.674	2.31
2021		117,513	23,503		116,293	29,984	980,794		46,019	21,488	7,167	**1,342,761**	5.0	1.35	2.83	0.05	**9.23**	**9.23**	8.56	0.668	2.31
2022		117,513	23,503		116,293	29,984	980,794		46,019	21,488	13,740	**1,349,334**	5.0	1.35	2.83	0.10	**9.28**	**9.28**	8.61	0.663	2.31
2023		117,513	23,503		116,293	29,984	980,794		46,019	21,488	20,365	**1,355,959**	5.0	1.35	2.83	0.14	**9.32**	**9.32**	8.67	0.657	2.31
2024		117,513	23,503		116,293	29,984	980,794		46,019	21,488	27,042	**1,362,636**	5.0	1.35	2.83	0.19	**9.37**	**9.37**	8.72	0.652	2.31
2025		117,513	23,503		116,293	29,984	980,794		46,019	21,488	33,771	**1,369,365**	5.0	1.35	2.83	0.24	**9.42**	**9.42**	8.77	0.646	2.31
2026		117,513	23,503		116,293	29,984	980,794		46,019	21,488	40,553	**1,376,147**	5.0	1.35	2.83	0.29	**9.47**	**9.47**	8.83	0.641	2.31
2027		117,513	23,503		116,293	29,984	980,794		46,019	21,488	47,387	**1,382,981**	5.0	1.35	2.83	0.34	**9.52**	**9.52**	8.88	0.635	2.31
2028		117,513	23,503		116,293	29,984	980,794		46,019	21,488	54,275	**1,389,868**	5.0	1.35	2.83	0.38	**9.56**	**9.56**	8.93	0.630	2.31
2029		117,513	23,503		116,293	29,984	980,794		46,019	21,488	61,215	**1,396,809**	5.0	1.35	2.83	0.43	**9.61**	**9.61**	8.99	0.624	2.31
2030		117,513	23,503		116,293	29,984	980,794		46,019	21,488	68,209	**1,403,803**	5.0	1.35	2.83	0.48	**9.66**	**9.66**	9.04	0.619	2.31
2031		117,513	23,503		116,293	29,984	980,794		46,019	21,488	75,256	**1,410,850**	5.0	1.35	2.83	0.53	**9.71**	**9.71**	9.10	0.614	2.31
2032		117,513	23,503		116,293	29,984	980,794		46,019	21,488	82,357	**1,417,951**	5.0	1.35	2.83	0.58	**9.76**	**9.76**	9.15	0.609	2.31
2033		117,513	23,503		116,293	29,984	980,794		46,019	21,488	89,513	**1,425,106**	5.0	1.35	2.83	0.63	**9.81**	**9.81**	9.21	0.603	2.31
2034		117,513	23,503		116,293	29,984	980,794		46,019	21,488	96,722	**1,432,316**	5.0	1.35	2.83	0.68	**9.86**	**9.86**	9.27	0.598	2.31
2035		117,513	23,503		116,293	29,984	980,794		46,019	21,488	103,986	**1,439,580**	5.0	1.35	2.83	0.74	**9.92**	**9.92**	9.32	0.593	2.31
2036		117,513	23,503		116,293	29,984	980,794		46,019	21,488	111,305	**1,446,899**	5.0	1.35	2.83	0.79	**9.97**	**9.97**	9.38	0.588	2.31
2037		117,513	23,503		116,293	29,984	980,794		46,019	21,488	118,679	**1,454,273**	5.0	1.35	2.83	0.84	**10.02**	**10.02**	9.44	0.583	2.31
2038		117,513	23,503		116,293	29,984	980,794		46,019	21,488	126,109	**1,461,702**	5.0	1.35	2.83	0.89	**10.07**	**10.07**	9.49	0.578	2.31
2039		117,513	23,503		116,293	29,984	980,794		46,019	21,488	133,594	**1,469,187**	5.0	1.35	2.83	0.95	**10.13**	**10.13**	9.55	0.573	2.31
2040		117,513	23,503		116,293	29,984	980,794		46,019	21,488	141,134	**1,476,728**	5.0	1.35	2.83	1.00	**10.18**	**10.18**	9.61	0.568	2.31
2041		117,513	23,503		116,293	29,984	980,794		46,019	21,488	148,731	**1,484,325**	5.0	1.35	2.83	1.05	**10.23**	**10.23**	9.67	0.564	2.31
2042		117,513	23,503		116,293	29,984	980,794		46,019	21,488	156,384	**1,491,977**	5.0	1.35	2.83	1.11	**10.29**	**10.29**	9.73	0.559	2.31
2043		117,513	23,503		116,293	29,984	980,794		46,019	21,488	164,093	**1,499,687**	5.0	1.35	2.83	1.16	**10.34**	**10.34**	9.79	0.554	2.31
2044		117,513	23,503		116,293	29,984	980,794		46,019	21,488	171,860	**1,507,453**	5.0	1.35	2.83	1.22	**10.40**	**10.40**	9.85	0.549	2.31
2045		117,513	23,503		116,293	29,984	980,794		46,019	21,488	179,683	**1,515,277**	5.00	1.35	2.83	1.27	**10.45**	**10.45**	9.91	0.545	2.31

NP Cost at 3%	106,238,581
NP Cost at 6%	89,118,860
NP Cost at 9%	79,231,538

Capital Cost:	86,860,736
Operation + Maintenance	354,800
Pumping Costs	1,160,477

OPTION 6

	OPTION 6																
COMPONENT	**Boosted Waterdown Pipeline (1)**				**Xonxa Pipeline**					**Flow Mm³/a**					**FLOW REQUIRED (Mm³/a)**		
CAPACITY	**600/500/450 mm diam**				**300 mm**												
	Construct Booster Pump	Maintenance Cost	Operation Cost	Pumping Cost	Construct Pipeline/ Pump	Maintenance Cost	Operation Cost	Pumping Cost	**TOTAL CASH FLOW**	Bongola	Boosted Waterdown Pipeline	Xonxa Pipeline	**Total Queenstown Supply**	**Total Queenstown Demand**	Total Queenstown Requirement	Rural Req.	Sada
YEAR										1.35	5.99		**7.34**	**7.34**	6.61	0.72	2.16
2003										1.35	6.15	0.65	**8.15**	**8.15**	7.41	0.746	2.207
2004	588,087				27,918,568				**28,506,655**	1.35	6.15	0.77	**8.27**	**8.27**	7.52	0.749	2.213
2005		24,993	882	145,937		120,074	35,564	336,029	**663,479**	1.35	6.15	0.81	**8.31**	**8.31**	7.57	0.743	2.220
2006		24,993	882	145,937		120,074	35,564	361,587	**689,037**	1.35	6.15	0.88	**8.38**	**8.38**	7.64	0.739	2.227
2007		24,993	882	145,937		120,074	35,564	387,391	**714,841**	1.35	6.15	0.94	**8.44**	**8.44**	7.70	0.735	2.233
2008		24,993	882	145,937		120,074	35,564	413,442	**740,893**	1.35	6.15	1.00	**8.50**	**8.50**	7.77	0.731	2.240
2009		24,993	882	145,937		120,074	35,564	439,744	**767,194**	1.35	6.15	1.06	**8.56**	**8.56**	7.84	0.727	2.247
2010		24,993	882	145,937		120,074	35,564	466,297	**793,747**	1.35	6.15	1.13	**8.63**	**8.63**	7.91	0.723	2.253
2011		24,993	882	145,937		120,074	35,564	493,104	**820,554**	1.35	6.15	1.19	**8.69**	**8.69**	7.97	0.719	2.260
2012		24,993	882	145,937		120,074	35,564	520,167	**847,617**	1.35	6.15	1.26	**8.76**	**8.76**	8.04	0.715	2.267
2013		24,993	882	145,937		120,074	35,564	547,488	**874,938**	1.35	6.15	1.32	**8.82**	**8.82**	8.11	0.711	2.274
2014		24,993	882	145,937		120,074	35,564	575,069	**902,519**	1.35	6.15	1.39	**8.89**	**8.89**	8.18	0.707	2.281
2015		24,993	882	145,937		120,074	35,564	602,912	**930,362**	1.35	6.15	1.46	**8.96**	**8.96**	8.26	0.704	2.287
2016		24,993	882	145,937		120,074	35,564	621,250	**948,700**	1.35	6.15	1.50	**9.00**	**9.00**	8.31	0.698	2.294
2017		24,993	882	145,937		120,074	35,564	639,735	**967,185**	1.35	6.15	1.55	**9.05**	**9.05**	8.36	0.692	2.301
2018		24,993	882	145,937		120,074	35,564	658,369	**985,819**	1.35	6.15	1.59	**9.09**	**9.09**	8.41	0.686	2.308
2019		24,993	882	145,937		120,074	35,564	677,152	**1,004,602**	1.35	6.15	1.64	**9.14**	**9.14**	8.46	0.680	2.315
2020		24,993	882	145,937		120,074	35,564	696,085	**1,023,535**	1.35	6.15	1.68	**9.18**	**9.18**	8.51	0.674	2.315
2021		24,993	882	145,937		120,074	35,564	715,168	**1,042,618**	1.35	6.15	1.73	**9.23**	**9.23**	8.56	0.668	2.315
2022		24,993	882	145,937		120,074	35,564	734,402	**1,061,852**	1.35	6.15	1.78	**9.28**	**9.28**	8.61	0.663	2.315
2023		24,993	882	145,937		120,074	35,564	753,788	**1,081,238**	1.35	6.15	1.82	**9.32**	**9.32**	8.67	0.657	2.315
2024		24,993	882	145,937		120,074	35,564	773,326	**1,100,776**	1.35	6.15	1.87	**9.37**	**9.37**	8.72	0.652	2.315
2025		24,993	882	145,937		120,074	35,564	793,017	**1,120,467**	1.35	6.15	1.92	**9.42**	**9.42**	8.77	0.646	2.315
2026		24,993	882	145,937		120,074	35,564	812,861	**1,140,311**	1.35	6.15	1.97	**9.47**	**9.47**	8.83	0.641	2.315
2027		24,993	882	145,937		120,074	35,564	832,860	**1,160,310**	1.35	6.15	2.02	**9.52**	**9.52**	8.88	0.635	2.315
2028		24,993	882	145,937		120,074	35,564	853,013	**1,180,463**	1.35	6.15	2.06	**9.56**	**9.56**	8.93	0.630	2.315
2029		24,993	882	145,937		120,074	35,564	873,322	**1,200,772**	1.35	6.15	2.11	**9.61**	**9.61**	8.99	0.624	2.315
2030		24,993	882	145,937		120,074	35,564	893,787	**1,221,237**	1.35	6.15	2.16	**9.66**	**9.66**	9.04	0.619	2.315
2031		24,993	882	145,937		120,074	35,564	914,409	**1,241,859**	1.35	6.15	2.21	**9.71**	**9.71**	9.10	0.614	2.315
2032		24,993	882	145,937		120,074	35,564	935,188	**1,262,639**	1.35	6.15	2.26	**9.76**	**9.76**	9.15	0.609	2.315
2033		24,993	882	145,937		120,074	35,564	956,126	**1,283,576**	1.35	6.15	2.31	**9.81**	**9.81**	9.21	0.603	2.315
2034		24,993	882	145,937		120,074	35,564	977,223	**1,304,673**	1.35	6.15	2.36	**9.86**	**9.86**	9.27	0.598	2.315
2035		24,993	882	145,937		120,074	35,564	998,479	**1,325,929**	1.35	6.15	2.42	**9.92**	**9.92**	9.32	0.593	2.315
2036		24,993	882	145,937		120,074	35,564	1,019,896	**1,347,346**	1.35	6.15	2.47	**9.97**	**9.97**	9.38	0.588	2.315
2037		24,993	882	145,937		120,074	35,564	1,041,473	**1,368,923**	1.35	6.15	2.52	**10.02**	**10.02**	9.44	0.583	2.315
2038		24,993	882	145,937		120,074	35,564	1,063,213	**1,390,663**	1.35	6.15	2.57	**10.07**	**10.07**	9.49	0.578	2.315
2039		24,993	882	145,937		120,074	35,564	1,085,115	**1,412,565**	1.35	6.15	2.63	**10.13**	**10.13**	9.55	0.573	2.315
2040		24,993	882	145,937		120,074	35,564	1,107,180	**1,434,630**	1.35	6.15	2.68	**10.18**	**10.18**	9.61	0.568	2.315
2041		24,993	882	145,937		120,074	35,564	1,129,409	**1,456,859**	1.35	6.15	2.73	**10.23**	**10.23**	9.67	0.564	2.315
2042		24,993	882	145,937		120,074	35,564	1,151,803	**1,479,253**	1.35	6.15	2.79	**10.29**	**10.29**	9.73	0.559	2.315
2043		24,993	882	145,937		120,074	35,564	1,174,363	**1,501,813**	1.35	6.15	2.84	**10.34**	**10.34**	9.79	0.554	2.315
2044		24,993	882	145,937		120,074	35,564	1,197,088	**1,524,538**	1.35	6.15	2.90	**10.40**	**10.40**	9.85	0.549	2.315
2045		24,993	882	145,937		120,074	35,564	1,219,981	**1,547,431**	1.35	6.15	2.95	**10.45**	**10.45**	9.91	0.545	2.315

(1) NOTE: ONLY ADDITIONAL COSTS OF BOOSTING FLOW ARE INCLUDED. OTHER COSTS ARE COMMON TO ALL OPTIONS AND ARE NOT INCLUDED.

NP Cost at 3%	51,140,559
NP Cost at 6%	40,575,218
NP Cost at 9%	35,059,350

Capital Cost :	28,506,655
Operation + Maintenance	181,513
Pumping Costs	1,365,918

OPTION 7

OPTION 7

COMPONENT / CAPACITY	Xonxa Pipeline 300 mm diam				Waklyn Weir 1Mm³/a			Waklyn Weir Pipeline 300 mm diam					FLOW (Mm³/a)						FLOW REQUIRED (Mm³/a)		
YEAR	Construct Weir	Maintenance Cost	Operation Cost	Pumping Cost	Construct Pipeline/ Pump	Maintenance Cost	Operation Cost	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	TOTAL CASH FLOW	Waterdown Pipeline (Existing)	Bongola	Xonxa Pipeline	Waklyn Weir Pipeline	Total Queenstown Supply	Total Queenstown Demand	Total Queensstown Requirement	Rural Req.	Sada
																			7.29	0.740	2.200
2003																			7.41	0.746	2.207
2004	27,720,536											27,720,536	5.0						7.52	0.749	2.213
2005		116,120	35,308	788,715								940,143	5.0	1.35	1.96		8.31	8.31	7.57	0.743	2.220
2006		127,498	41,883	813,564								982,945	5.0	1.35	2.03		8.38	8.38	7.64	0.739	2.227
2007		127,498	41,883	838,652								1,008,033	5.0	1.35	2.09		8.44	8.44	7.70	0.735	2.233
2008		127,498	41,883	863,980								1,033,361	5.0	1.35	2.15		8.50	8.50	7.77	0.731	2.240
2009		127,498	41,883	889,552								1,058,933	5.0	1.35	2.21		8.56	8.56	7.84	0.727	2.247
2010		127,498	41,883	915,368								1,084,749	5.0	1.35	2.28		8.63	8.63	7.91	0.723	2.253
2011		127,498	41,883	941,432								1,110,813	5.0	1.35	2.34		8.69	8.69	7.97	0.719	2.260
2012		127,498	41,883	967,744								1,137,125	5.0	1.35	2.41		8.76	8.76	8.04	0.715	2.267
2013		127,498	41,883	994,307								1,163,688	5.0	1.35	2.47		8.82	8.82	8.11	0.711	2.274
2014		127,498	41,883	1,021,122								1,190,503	5.0	1.35	2.54		8.89	8.89	8.18	0.707	2.281
2015		127,498	41,883	1,048,193								1,217,574	5.0	1.35	2.61		8.96	8.96	8.26	0.704	2.287
2016		127,498	41,883	1,066,022								1,235,403	5.0	1.35	2.65		9.00	9.00	8.31	0.698	2.294
2017		127,498	41,883	1,083,995								1,253,376	5.0	1.35	2.70		9.05	9.05	8.36	0.692	2.301
2018		127,498	41,883	1,102,112								1,271,493	5.0	1.35	2.74		9.09	9.09	8.41	0.686	2.308
2019		127,498	41,883	1,120,373	47,005,250			17,028,093				65,323,098	5.0	1.35	2.79		9.14	9.14	8.46	0.680	2.315
2020		127,498	41,883	1,138,781		117,513	23,503		46,019	21,488	0	1,516,685	5.0	1.35	2.83		9.18	9.18	8.51	0.674	2.315
2021		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	7,167	1,522,015	5.0	1.35	2.83	0.05	9.23	9.23	8.56	0.668	2.315
2022		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	13,740	1,528,588	5.0	1.35	2.83	0.10	9.28	9.28	8.61	0.663	2.315
2023		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	20,365	1,535,213	5.0	1.35	2.83	0.14	9.32	9.32	8.67	0.657	2.315
2024		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	27,042	1,541,890	5.0	1.35	2.83	0.19	9.37	9.37	8.72	0.652	2.315
2025		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	33,771	1,548,619	5.0	1.35	2.83	0.24	9.42	9.42	8.77	0.646	2.315
2026		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	40,553	1,555,401	5.0	1.35	2.83	0.29	9.47	9.47	8.83	0.641	2.315
2027		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	47,387	1,562,235	5.0	1.35	2.83	0.34	9.52	9.52	8.88	0.635	2.315
2028		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	54,275	1,569,122	5.0	1.35	2.83	0.38	9.56	9.56	8.93	0.630	2.315
2029		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	61,215	1,576,063	5.0	1.35	2.83	0.43	9.61	9.61	8.99	0.624	2.315
2030		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	68,209	1,583,057	5.0	1.35	2.83	0.48	9.66	9.66	9.04	0.619	2.315
2031		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	75,256	1,590,104	5.0	1.35	2.83	0.53	9.71	9.71	9.10	0.614	2.315
2032		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	82,357	1,597,205	5.0	1.35	2.83	0.58	9.76	9.76	9.15	0.609	2.315
2033		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	89,513	1,604,360	5.0	1.35	2.83	0.63	9.81	9.81	9.21	0.603	2.315
2034		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	96,722	1,611,570	5.0	1.35	2.83	0.68	9.86	9.86	9.27	0.598	2.315
2035		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	103,986	1,618,834	5.0	1.35	2.83	0.74	9.92	9.92	9.32	0.593	2.315
2036		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	111,305	1,626,153	5.0	1.35	2.83	0.79	9.97	9.97	9.38	0.588	2.315
2037		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	118,679	1,633,527	5.0	1.35	2.83	0.84	10.02	10.02	9.44	0.583	2.315
2038		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	126,109	1,640,956	5.0	1.35	2.83	0.89	10.07	10.07	9.49	0.578	2.315
2039		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	133,594	1,648,441	5.0	1.35	2.83	0.95	10.13	10.13	9.55	0.573	2.315
2040		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	141,134	1,655,982	5.0	1.35	2.83	1.00	10.18	10.18	9.61	0.568	2.315
2041		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	148,731	1,663,579	5.0	1.35	2.83	1.05	10.23	10.23	9.67	0.564	2.315
2042		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	156,384	1,671,231	5.0	1.35	2.83	1.11	10.29	10.29	9.73	0.559	2.315
2043		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	164,093	1,678,941	5.0	1.35	2.83	1.16	10.34	10.34	9.79	0.554	2.315
2044		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	171,860	1,686,707	5.0	1.35	2.83	1.22	10.40	10.40	9.85	0.549	2.315
2045		127,498	41,883	1,136,944		117,513	23,503		46,019	21,488	179,683	1,694,531	5.00	1.35	2.83	1.27	10.45	10.45	9.91	0.545	2.315

NP Cost at 3%	97,495,985
NP Cost at 6%	69,569,268
NP Cost at 9%	53,566,991

Capital Cost:	91,753,879
Operation + Maintenance	377,904
Pumping Costs	1,316,627

OPTION 8

Xonxa Pipeline 300 mm diam				Xonxa Pipeline 200mm diam				TOTAL CASH FLOW	Flow (Mm^3/a)					
Construct Pipeline	Maintenance Cost	Operation Cost	Pumping Cost	Construct Pipeline	Maintenance Cost	Operation Cost	Pumping Cost		Waterdown Pipeline (Existing)	Bongola	Xonxa Pipeline 1	Xonxa Pipeline 2	**Total Queenstown Supply**	Total Queenstown Demand
27,720,536								**27,720,536**	5.0					
	116,120	35,308	788,715					**940,143**	5.0	1.35	1.96		**8.31**	8.31
	127,498	41,883	813,564					**982,945**	5.0	1.35	2.03		**8.38**	8.38
	127,498	41,883	838,652					**1,008,033**	5.0	1.35	2.09		**8.44**	8.44
	127,498	41,883	863,980					**1,033,361**	5.0	1.35	2.15		**8.50**	8.50
	127,498	41,883	889,552					**1,058,933**	5.0	1.35	2.21		**8.56**	8.56
	127,498	41,883	915,368					**1,084,749**	5.0	1.35	2.28		**8.63**	8.63
	127,498	41,883	941,432					**1,110,813**	5.0	1.35	2.34		**8.69**	8.69
	127,498	41,883	967,744					**1,137,125**	5.0	1.35	2.41		**8.76**	8.76
	127,498	41,883	994,307					**1,163,688**	5.0	1.35	2.47		**8.82**	8.82
	127,498	41,883	1,021,122					**1,190,503**	5.0	1.35	2.54		**8.89**	8.89
	127,498	41,883	1,048,193					**1,217,574**	5.0	1.35	2.61		**8.96**	8.96
	127,498	41,883	1,066,022					**1,235,403**	5.0	1.35	2.65		**9.00**	9.00
	127,498	41,883	1,083,995					**1,253,376**	5.0	1.35	2.70		**9.05**	9.05
	127,498	41,883	1,102,112					**1,271,493**	5.0	1.35	2.74		**9.09**	9.09
	127,498	41,883	1,120,373					**1,289,754**	5.0	1.35	2.79		**9.14**	9.14
	127,498	41,883	1,138,781	17,218,061				**18,526,223**	5.0	1.35	2.83		**9.18**	9.18
	127,498	41,883	1,136,944		60,261	21,733	18,451	**1,406,770**	5.0	1.35	2.83	0.05	**9.23**	9.23
	127,498	41,883	1,136,944		60,261	21,733	35,373	**1,423,692**	5.0	1.35	2.83	0.10	**9.28**	9.28
	127,498	41,883	1,136,944		60,261	21,733	52,429	**1,440,748**	5.0	1.35	2.83	0.14	**9.32**	9.32
	127,498	41,883	1,136,944		60,261	21,733	69,618	**1,457,937**	5.0	1.35	2.83	0.19	**9.37**	9.37
	127,498	41,883	1,136,944		60,261	21,733	86,942	**1,475,261**	5.0	1.35	2.83	0.24	**9.42**	9.42
	127,498	41,883	1,136,944		60,261	21,733	104,401	**1,492,720**	5.0	1.35	2.83	0.29	**9.47**	9.47
	127,498	41,883	1,136,944		60,261	21,733	121,996	**1,510,315**	5.0	1.35	2.83	0.34	**9.52**	9.52
	127,498	41,883	1,136,944		60,261	21,733	139,726	**1,528,045**	5.0	1.35	2.83	0.38	**9.56**	9.56
	127,498	41,883	1,136,944		60,261	21,733	157,594	**1,545,913**	5.0	1.35	2.83	0.43	**9.61**	9.61
	127,498	41,883	1,136,944		60,261	21,733	175,599	**1,563,918**	5.0	1.35	2.83	0.48	**9.66**	9.66
	127,498	41,883	1,136,944		60,261	21,733	193,742	**1,582,061**	5.0	1.35	2.83	0.53	**9.71**	9.71
	127,498	41,883	1,136,944		60,261	21,733	212,024	**1,600,343**	5.0	1.35	2.83	0.58	**9.76**	9.76
	127,498	41,883	1,136,944		60,261	21,733	230,445	**1,618,764**	5.0	1.35	2.83	0.63	**9.81**	9.81
	127,498	41,883	1,136,944		60,261	21,733	249,005	**1,637,324**	5.0	1.35	2.83	0.68	**9.86**	9.86
	127,498	41,883	1,136,944		60,261	21,733	267,706	**1,656,025**	5.0	1.35	2.83	0.74	**9.92**	9.92
	127,498	41,883	1,136,944		60,261	21,733	286,548	**1,674,867**	5.0	1.35	2.83	0.79	**9.97**	9.97
	127,498	41,883	1,136,944		60,261	21,733	305,532	**1,693,851**	5.0	1.35	2.83	0.84	**10.02**	10.02
	127,498	41,883	1,136,944		60,261	21,733	324,659	**1,712,978**	5.0	1.35	2.83	0.89	**10.07**	10.07
	127,498	41,883	1,136,944		60,261	21,733	343,928	**1,732,247**	5.0	1.35	2.83	0.95	**10.13**	10.13
	127,498	41,883	1,136,944		60,261	21,733	363,340	**1,751,659**	5.0	1.35	2.83	1.00	**10.18**	10.18
	127,498	41,883	1,136,944		60,261	21,733	382,898	**1,771,217**	5.0	1.35	2.83	1.05	**10.23**	10.23
	127,498	41,883	1,136,944		60,261	21,733	402,600	**1,790,919**	5.0	1.35	2.83	1.11	**10.29**	10.29
	127,498	41,883	1,136,944		60,261	21,733	422,447	**1,810,766**	5.0	1.35	2.83	1.16	**10.34**	10.34
	127,498	41,883	1,136,944		60,261	21,733	442,441	**1,830,760**	5.0	1.35	2.83	1.22	**10.40**	10.40
	127,498	41,883	1,136,944		60,261	21,733	462,582	**1,850,901**	5.00	1.35	2.83	1.27	**10.45**	10.45

NPCOST AT 3%	67,877,597
NPCOST AT 6%	50,601,901
NPCOST AT9%	41,300,768

Capital Cost :	44,938,597
Operation + Maintenance	251,375
Pumping Costs	1,599,526

OPTION 9

OPTION 9

COMPONENT CAPACITY	Stitchel Weir 1 Mm^3/a			Stitchel Weir Pipeline 500 mm diam				Stitchel Weir Pipeline 200 mm diam					FLOW SUPPLIED (Mm^3/a)					FLOW REQUIRED (Mm^3/a)		
	Construct Weir	Maintenance Cost	Operation Cost	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	**TOTAL CASH FLOW**	Bongola	Stitchel Weir Pipeline	Stitchel Weir Pipeline 2	**Total Queenstown Supply**	**Total Queenstown Demand**	Total Queenstown Requirement	Rural Req.	Sada
YEAR																		7.29	0.740	2.200
2003																		7.41	0.746	2.207
2004	44,604,408			35,329,397								79,933,805						7.52	0.749	2.213
2005		111,511	22,302		211,945	45,143	1,921,037					2,311,938	1.35	6.96		**8.31**	**8.31**	7.57	0.743	2.220
2006		111,511	22,302		211,945	45,143	1,938,101					2,329,002	1.35	7.03		**8.38**	**8.38**	7.64	0.739	2.227
2007		111,511	22,302		211,945	45,143	1,955,329					2,346,230	1.35	7.09		**8.44**	**8.44**	7.70	0.735	2.233
2008		111,511	22,302		211,945	45,143	1,972,723					2,363,624	1.35	7.15		**8.50**	**8.50**	7.77	0.731	2.240
2009		111,511	22,302		211,945	45,143	1,990,283					2,381,184	1.35	7.21		**8.56**	**8.56**	7.84	0.727	2.247
2010		111,511	22,302		211,945	45,143	2,008,011					2,398,913	1.35	7.28		**8.63**	**8.63**	7.91	0.723	2.253
2011		111,511	22,302		211,945	45,143	2,025,909					2,416,810	1.35	7.34		**8.69**	**8.69**	7.97	0.719	2.260
2012		111,511	22,302		211,945	45,143	2,043,978					2,434,879	1.35	7.41		**8.76**	**8.76**	8.04	0.715	2.267
2013		111,511	22,302		211,945	45,143	2,062,219					2,453,120	1.35	7.47		**8.82**	**8.82**	8.11	0.711	2.274
2014		111,511	22,302		211,945	45,143	2,080,634					2,471,535	1.35	7.54		**8.89**	**8.89**	8.18	0.707	2.281
2015		111,511	22,302		211,945	45,143	2,099,224					2,490,125	1.35	7.61		**8.96**	**8.96**	8.26	0.704	2.287
2016		111,511	22,302		211,945	45,143	2,111,467					2,502,368	1.35	7.65		**9.00**	**9.00**	8.31	0.698	2.294
2017		111,511	22,302		211,945	45,143	2,123,809					2,514,710	1.35	7.70		**9.05**	**9.05**	8.36	0.692	2.301
2018		111,511	22,302		211,945	45,143	2,136,250					2,527,151	1.35	7.74		**9.09**	**9.09**	8.41	0.686	2.308
2019		111,511	22,302		211,945	45,143	2,148,790					2,539,692	1.35	7.79		**9.14**	**9.14**	8.46	0.680	2.315
2020		111,511	22,302		211,945	45,143	2,161,431	14,373,497				16,925,829	1.35	7.83		**9.18**	**9.18**	8.51	0.674	2.315
2021		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	13,733	2,635,365	1.35	7.83	0.05	**9.23**	**9.23**	8.56	0.668	2.315
2022		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	27,575	2,649,206	1.35	7.83	0.09	**9.28**	**9.28**	8.61	0.663	2.315
2023		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	41,526	2,663,158	1.35	7.83	0.14	**9.32**	**9.32**	8.67	0.657	2.315
2024		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	55,587	2,677,218	1.35	7.83	0.19	**9.37**	**9.37**	8.72	0.652	2.315
2025		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	69,758	2,691,389	1.35	7.83	0.23	**9.42**	**9.42**	8.77	0.646	2.315
2026		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	84,039	2,705,670	1.35	7.83	0.28	**9.47**	**9.47**	8.83	0.641	2.315
2027		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	98,431	2,720,062	1.35	7.83	0.33	**9.52**	**9.52**	8.88	0.635	2.315
2028		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	112,934	2,734,566	1.35	7.83	0.38	**9.56**	**9.56**	8.93	0.630	2.315
2029		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	127,550	2,749,181	1.35	7.83	0.43	**9.61**	**9.61**	8.99	0.624	2.315
2030		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	142,278	2,763,909	1.35	7.83	0.48	**9.66**	**9.66**	9.04	0.619	2.315
2031		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	157,118	2,778,750	1.35	7.83	0.53	**9.71**	**9.71**	9.10	0.614	2.315
2032		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	172,072	2,793,704	1.35	7.83	0.58	**9.76**	**9.76**	9.15	0.609	2.315
2033		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	187,140	2,808,772	1.35	7.83	0.63	**9.81**	**9.81**	9.21	0.603	2.315
2034		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	202,323	2,823,954	1.35	7.83	0.68	**9.86**	**9.86**	9.27	0.598	2.315
2035		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	217,620	2,839,251	1.35	7.83	0.73	**9.92**	**9.92**	9.32	0.593	2.315
2036		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	233,032	2,854,664	1.35	7.83	0.78	**9.97**	**9.97**	9.38	0.588	2.315
2037		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	248,561	2,870,192	1.35	7.83	0.84	**10.02**	**10.02**	9.44	0.583	2.315
2038		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	264,206	2,885,837	1.35	7.83	0.89	**10.07**	**10.07**	9.49	0.578	2.315
2039		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	279,968	2,901,599	1.35	7.83	0.94	**10.13**	**10.13**	9.55	0.573	2.315
2040		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	295,847	2,917,478	1.35	7.83	0.99	**10.18**	**10.18**	9.61	0.568	2.315
2041		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	311,844	2,933,476	1.35	7.83	1.05	**10.23**	**10.23**	9.67	0.564	2.315
2042		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	327,960	2,949,592	1.35	7.83	1.10	**10.29**	**10.29**	9.73	0.559	2.315
2043		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	344,195	2,965,827	1.35	7.83	1.16	**10.34**	**10.34**	9.79	0.554	2.315
2044		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	360,550	2,982,181	1.35	7.83	1.21	**10.40**	**10.40**	9.85	0.549	2.315
2045		111,511	22,302		211,945	45,143	2,161,431		51,213	18,086	377,025	2,998,656	1.35	7.83	1.27	**10.45**	**10.45**	9.91	0.545	2.315

NP Cost at 3%	145,307,579
NP Cost at 6%	116,952,021
NP Cost at 9%	101,274,869

Capital Cost :	94,307,302
Operation + Maintenance	460,200
Pumping Costs	2,538,456

OPTION 10

OPTION 10

COMPONENT CAPACITY	Xonxa Pipeline 500 mm diam				Stitchel Weir $1Mm^3/a$			Stitchel Weir Pipeline 200 mm diam					FLOW (Mm^3/a)					FLOW REQUIRED (Mm^3/a)		
	Construct Weir	Maintenance Cost	Operation Cost	Pumping Cost	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	TOTAL CASH FLOW	Bongola	Xonxa Pipeline	Stitchel Weir Pipeline 2	Total Queenstown Supply	Total Queenstown Demand	Total Queenstown Requirement	Rural Req.	Sada
YEAR																		7.29	0.740	2.200
2003																		7.41	0.746	2.207
2004	53,011,019											53,011,019	1.35	6.92				7.52	0.749	2.213
2005		260,834	67,997	2,483,258								2,812,089	1.35	6.96		8.31	8.31	7.57	0.743	2.220
2006		260,834	67,997	2,505,316								2,834,147	1.35	7.03		8.38	8.38	7.64	0.739	2.227
2007		260,834	67,997	2,527,586								2,856,417	1.35	7.09		8.44	8.44	7.70	0.735	2.233
2008		260,834	67,997	2,550,070								2,878,901	1.35	7.15		8.50	8.50	7.77	0.731	2.240
2009		260,834	67,997	2,572,770								2,901,601	1.35	7.21		8.56	8.56	7.84	0.727	2.247
2010		260,834	67,997	2,595,687								2,924,518	1.35	7.28		8.63	8.63	7.91	0.723	2.253
2011		260,834	67,997	2,618,823								2,947,654	1.35	7.34		8.69	8.69	7.97	0.719	2.260
2012		260,834	67,997	2,642,179								2,971,010	1.35	7.41		8.76	8.76	8.04	0.715	2.267
2013		260,834	67,997	2,665,759								2,994,590	1.35	7.47		8.82	8.82	8.11	0.711	2.274
2014		260,834	67,997	2,689,563								3,018,394	1.35	7.54		8.89	8.89	8.18	0.707	2.281
2015		260,834	67,997	2,713,594								3,042,425	1.35	7.61		8.96	8.96	8.26	0.704	2.287
2016		260,834	67,997	2,729,420								3,058,251	1.35	7.65		9.00	9.00	8.31	0.698	2.294
2017		260,834	67,997	2,745,374								3,074,205	1.35	7.70		9.05	9.05	8.36	0.692	2.301
2018		260,834	67,997	2,761,456								3,090,287	1.35	7.74		9.09	9.09	8.41	0.686	2.308
2019		260,834	67,997	2,777,667	44,604,408							47,710,905	1.35	7.79		9.14	9.14	8.46	0.680	2.315
2020		260,834	67,997	2,794,007		111,511	22,302	14,373,497				17,630,148	1.35	7.83	0.00	9.18	9.18	8.51	0.674	2.315
2021		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	13,733	3,339,684	1.35	7.83	0.05	9.23	9.23	8.56	0.668	2.315
2022		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	27,575	3,353,525	1.35	7.83	0.09	9.28	9.28	8.61	0.663	2.315
2023		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	41,526	3,367,477	1.35	7.83	0.14	9.32	9.32	8.67	0.657	2.315
2024		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	55,587	3,381,537	1.35	7.83	0.19	9.37	9.37	8.72	0.652	2.315
2025		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	69,758	3,395,708	1.35	7.83	0.23	9.42	9.42	8.77	0.646	2.315
2026		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	84,039	3,409,989	1.35	7.83	0.28	9.47	9.47	8.83	0.641	2.315
2027		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	98,431	3,424,381	1.35	7.83	0.33	9.52	9.52	8.88	0.635	2.315
2028		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	112,934	3,438,885	1.35	7.83	0.38	9.56	9.56	8.93	0.630	2.315
2029		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	127,550	3,453,500	1.35	7.83	0.43	9.61	9.61	8.99	0.624	2.315
2030		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	142,278	3,468,228	1.35	7.83	0.48	9.66	9.66	9.04	0.619	2.315
2031		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	157,118	3,483,069	1.35	7.83	0.53	9.71	9.71	9.10	0.614	2.315
2032		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	172,072	3,498,023	1.35	7.83	0.58	9.76	9.76	9.15	0.609	2.315
2033		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	187,140	3,513,091	1.35	7.83	0.63	9.81	9.81	9.21	0.603	2.315
2034		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	202,323	3,528,273	1.35	7.83	0.68	9.86	9.86	9.27	0.598	2.315
2035		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	217,620	3,543,570	1.35	7.83	0.73	9.92	9.92	9.32	0.593	2.315
2036		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	233,032	3,558,983	1.35	7.83	0.78	9.97	9.97	9.38	0.588	2.315
2037		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	248,561	3,574,511	1.35	7.83	0.84	10.02	10.02	9.44	0.583	2.315
2038		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	264,206	3,590,156	1.35	7.83	0.89	10.07	10.07	9.49	0.578	2.315
2039		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	279,968	3,605,918	1.35	7.83	0.94	10.13	10.13	9.55	0.573	2.315
2040		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	295,847	3,621,797	1.35	7.83	0.99	10.18	10.18	9.61	0.568	2.315
2041		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	311,844	3,637,795	1.35	7.83	1.05	10.23	10.23	9.67	0.564	2.315
2042		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	327,960	3,653,911	1.35	7.83	1.10	10.29	10.29	9.73	0.559	2.315
2043		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	344,195	3,670,146	1.35	7.83	1.16	10.34	10.34	9.79	0.554	2.315
2044		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	360,550	3,686,500	1.35	7.83	1.21	10.40	10.40	9.85	0.549	2.315
2045		260,834	67,997	2,794,007		111,511	22,302		51,213	18,086	377,025	3,702,975	1.35	7.83	1.27	10.45	10.45	9.91	0.545	2.315

NP Cost at 3%	160,984,325
NP Cost at 6%	117,573,025
NP Cost at9%	93,472,501

Capital Cost:	111,988,924
Operation + Maintenance	531,943
Pumping Costs	3,171,032

OPTION 11

OPTION 11

COMPONENT	Stitchel Weir			Stitchel Weir Pipeline				Xonxa Pipeline												
CAPACITY	$1Mm^3/a$			500 mm diam				200 mm diam					FLOW (Mm^3/a)					FLOW REQUIRED (Mm^3/a)		
	Construct Weir	Maintenance Cost	Operation Cost	Construct Pipeline/ Pump	Maintenance Cost	Operation Cost	Pumping Cost	Construct Pipeline/ Pump	Maintenance Cost	Operation Cost	Pumping Cost	TOTAL CASH FLOW	Bongola	Stitchel Weir Pipeline	Xonxa Pipeline	Total Queenstown Supply	Total Queenstown Demand	Total Queenstown Requirement	Rural Req.	Sada
YEAR																		7.29	0.740	2.200
2003	44,604,408											44,604,408						7.41	0.746	2.207
2004		111511.02	22302.204	35,329,397								35,463,210	1.35	6.92				7.52	0.749	2.213
2005		111,511	22,302		211,945	45,143	1,921,037					2,311,938	1.35	6.96		8.31	8.31	7.57	0.743	2.220
2006		111,511	22,302		211,945	45,143	1,938,101					2,329,002	1.35	7.03		8.38	8.38	7.64	0.739	2.227
2007		111,511	22,302		211,945	45,143	1,955,329					2,346,230	1.35	7.09		8.44	8.44	7.70	0.735	2.233
2008		111,511	22,302		211,945	45,143	1,972,723					2,363,624	1.35	7.15		8.50	8.50	7.77	0.731	2.240
2009		111,511	22,302		211,945	45,143	1,990,283					2,381,184	1.35	7.21		8.56	8.56	7.84	0.727	2.247
2010		111,511	22,302		211,945	45,143	2,008,011					2,398,913	1.35	7.28		8.63	8.63	7.91	0.723	2.253
2011		111,511	22,302		211,945	45,143	2,025,909					2,416,810	1.35	7.34		8.69	8.69	7.97	0.719	2.260
2012		111,511	22,302		211,945	45,143	2,043,978					2,434,879	1.35	7.41		8.76	8.76	8.04	0.715	2.267
2013		111,511	22,302		211,945	45,143	2,062,219					2,453,120	1.35	7.47		8.82	8.82	8.11	0.711	2.274
2014		111,511	22,302		211,945	45,143	2,080,634					2,471,535	1.35	7.54		8.89	8.89	8.18	0.707	2.281
2015		111,511	22,302		211,945	45,143	2,099,224					2,490,125	1.35	7.61		8.96	8.96	8.26	0.704	2.287
2016		111,511	22,302		211,945	45,143	2,111,467					2,502,368	1.35	7.65		9.00	9.00	8.31	0.698	2.294
2017		111,511	22,302		211,945	45,143	2,123,809					2,514,710	1.35	7.70		9.05	9.05	8.36	0.692	2.301
2018		111,511	22,302		211,945	45,143	2,136,250					2,527,151	1.35	7.74		9.09	9.09	8.41	0.686	2.308
2019		111,511	22,302		211,945	45,143	2,148,790					2,539,692	1.35	7.79		9.14	9.14	8.46	0.680	2.315
2020		111,511	22,302		211,945	45,143	2,161,431	17,218,061				19,770,393	1.35	7.83	0.00	9.18	9.18	8.51	0.674	2.315
2021		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	16,850	2,651,176	1.35	7.83	0.05	9.23	9.23	8.56	0.668	2.315
2022		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	33,833	2,668,159	1.35	7.83	0.09	9.28	9.28	8.61	0.663	2.315
2023		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	50,950	2,685,276	1.35	7.83	0.14	9.32	9.32	8.67	0.657	2.315
2024		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	68,201	2,702,527	1.35	7.83	0.19	9.37	9.37	8.72	0.652	2.315
2025		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	85,587	2,719,914	1.35	7.83	0.23	9.42	9.42	8.77	0.646	2.315
2026		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	103,109	2,737,436	1.35	7.83	0.28	9.47	9.47	8.83	0.641	2.315
2027		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	120,767	2,755,094	1.35	7.83	0.33	9.52	9.52	8.88	0.635	2.315
2028		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	138,562	2,772,888	1.35	7.83	0.38	9.56	9.56	8.93	0.630	2.315
2029		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	156,494	2,790,820	1.35	7.83	0.43	9.61	9.61	8.99	0.624	2.315
2030		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	174,564	2,808,890	1.35	7.83	0.48	9.66	9.66	9.04	0.619	2.315
2031		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	192,773	2,827,099	1.35	7.83	0.53	9.71	9.71	9.10	0.614	2.315
2032		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	211,120	2,845,446	1.35	7.83	0.58	9.76	9.76	9.15	0.609	2.315
2033		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	229,607	2,863,934	1.35	7.83	0.63	9.81	9.81	9.21	0.603	2.315
2034		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	248,235	2,882,561	1.35	7.83	0.68	9.86	9.86	9.27	0.598	2.315
2035		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	267,004	2,901,330	1.35	7.83	0.73	9.92	9.92	9.32	0.593	2.315
2036		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	285,914	2,920,240	1.35	7.83	0.78	9.97	9.97	9.38	0.588	2.315
2037		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	304,966	2,939,292	1.35	7.83	0.84	10.02	10.02	9.44	0.583	2.315
2038		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	324,161	2,958,487	1.35	7.83	0.89	10.07	10.07	9.49	0.578	2.315
2039		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	343,500	2,977,826	1.35	7.83	0.94	10.13	10.13	9.55	0.573	2.315
2040		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	362,983	2,997,309	1.35	7.83	0.99	10.18	10.18	9.61	0.568	2.315
2041		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	382,610	3,016,936	1.35	7.83	1.05	10.23	10.23	9.67	0.564	2.315
2042		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	402,383	3,036,710	1.35	7.83	1.10	10.29	10.29	9.73	0.559	2.315
2043		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	422,302	3,056,629	1.35	7.83	1.16	10.34	10.34	9.79	0.554	2.315
2044		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	442,369	3,076,695	1.35	7.83	1.21	10.40	10.40	9.85	0.549	2.315
2045		111,511	22,302		211,945	45,143	2,161,431		60,261	21,733	462,582	3,096,908	1.35	7.83	1.27	10.45	10.45	9.91	0.545	2.315

NP Cost at 3%	144,651,394
NP Cost at 6%	114,034,874
NP Cost at 9%	97,093,877

Capital Cost :	97,151,866
Operation + Maintenance	472,895
Pumping Costs	2,624,013

OPTION 12

OPTION 12

COMPONENT	Xonxa Pipeline											
CAPACITY	600 mm diam					FLOW (Mm³/a)				FLOW REQUIRED (Mm³/a)		
	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	TOTAL CASH FLOW	Bongola	Xonxa Pipeline	Total Queenstown Supply	Total Queenstown Demand	Total Queenstown Requirement	Rural Req.	Sada
YEAR										7.29	0.740	2.200
2003										7.41	0.746	2.207
2004	60,485,117				60,485,117					7.45	0.749	2.213
2005		281,443	77,658	2,038,970	2,398,071	1.35	6.91	8.26	8.26	7.52	0.743	2.220
2006		281,443	77,658	2,057,085	2,416,186	1.35	6.97	8.32	8.32	7.58	0.739	2.227
2007		281,443	77,658	2,075,374	2,434,475	1.35	7.03	8.38	8.38	7.65	0.735	2.233
2008		281,443	77,658	2,093,838	2,452,939	1.35	7.09	8.44	8.44	7.71	0.731	2.240
2009		281,443	77,658	2,112,480	2,471,581	1.35	7.16	8.51	8.51	7.78	0.727	2.247
2010		281,443	77,658	2,131,300	2,490,401	1.35	7.22	8.57	8.57	7.85	0.723	2.253
2011		281,443	77,658	2,150,301	2,509,402	1.35	7.29	8.64	8.64	7.92	0.719	2.260
2012		281,443	77,658	2,169,483	2,528,584	1.35	7.35	8.70	8.70	7.99	0.715	2.267
2013		281,443	77,658	2,188,848	2,547,949	1.35	7.42	8.77	8.77	8.05	0.711	2.274
2014		281,443	77,658	2,208,397	2,567,498	1.35	7.48	8.83	8.83	8.12	0.707	2.281
2015		281,443	77,658	2,221,898	2,580,999	1.35	7.53	8.88	8.88	8.17	0.704	2.287
2016		281,443	77,658	2,234,850	2,593,951	1.35	7.57	8.92	8.92	8.22	0.698	2.294
2017		281,443	77,658	2,247,907	2,607,008	1.35	7.62	8.97	8.97	8.27	0.692	2.301
2018		281,443	77,658	2,261,069	2,620,170	1.35	7.66	9.01	9.01	8.32	0.686	2.308
2019		281,443	77,658	2,274,337	2,633,438	1.35	7.71	9.06	9.06	8.38	0.680	2.315
2020		281,443	77,658	2,287,711	2,646,812	1.35	7.75	9.10	9.10	8.43	0.674	2.315
2021		281,443	77,658	2,301,191	2,660,292	1.35	7.80	9.15	9.15	8.48	0.668	2.315
2022		281,443	77,658	2,314,778	2,673,879	1.35	7.84	9.19	9.19	8.53	0.663	2.315
2023		281,443	77,658	2,328,473	2,687,574	1.35	7.89	9.24	9.24	8.58	0.657	2.315
2024		281,443	77,658	2,342,275	2,701,376	1.35	7.94	9.29	9.29	8.63	0.652	2.315
2025		281,443	77,658	2,356,186	2,715,287	1.35	7.98	9.33	9.33	8.69	0.646	2.315
2026		281,443	77,658	2,370,205	2,729,306	1.35	8.03	9.38	9.38	8.74	0.641	2.315
2027		281,443	77,658	2,384,334	2,743,435	1.35	8.08	9.43	9.43	8.79	0.635	2.315
2028		281,443	77,658	2,398,572	2,757,673	1.35	8.13	9.48	9.48	8.85	0.630	2.315
2029		281,443	77,658	2,412,920	2,772,021	1.35	8.18	9.53	9.53	8.90	0.624	2.315
2030		281,443	77,658	2,427,379	2,786,480	1.35	8.22	9.57	9.57	8.95	0.619	2.315
2031		281,443	77,658	2,441,949	2,801,050	1.35	8.27	9.62	9.62	9.01	0.614	2.315
2032		281,443	77,658	2,456,631	2,815,732	1.35	8.32	9.67	9.67	9.06	0.609	2.315
2033		281,443	77,658	2,471,425	2,830,526	1.35	8.37	9.72	9.72	9.12	0.603	2.315
2034		281,443	77,658	2,486,331	2,845,432	1.35	8.42	9.77	9.77	9.18	0.598	2.315
2035		281,443	77,658	2,501,350	2,860,451	1.35	8.47	9.82	9.82	9.23	0.593	2.315
2036		281,443	77,658	2,516,483	2,875,584	1.35	8.53	9.88	9.88	9.29	0.588	2.315
2037		281,443	77,658	2,531,729	2,890,830	1.35	8.58	9.93	9.93	9.34	0.583	2.315
2038		281,443	77,658	2,547,091	2,906,192	1.35	8.63	9.98	9.98	9.40	0.578	2.315
2039		281,443	77,658	2,562,567	2,921,668	1.35	8.68	10.03	10.03	9.46	0.573	2.315
2040		281,443	77,658	2,578,159	2,937,260	1.35	8.73	10.08	10.08	9.52	0.568	2.315
2041		281,443	77,658	2,593,867	2,952,968	1.35	8.79	10.14	10.14	9.57	0.564	2.315
2042		281,443	77,658	2,609,692	2,968,793	1.35	8.84	10.19	10.19	9.63	0.559	2.315
2043		281,443	77,658	2,625,633	2,984,734	1.35	8.90	10.25	10.25	9.69	0.554	2.315
2044		281,443	77,658	2,641,693	3,000,794	1.35	8.95	10.30	10.30	9.75	0.549	2.315
2045		281,443	77,658	2,686,651	3,045,752	1.35	9.10	10.45	10.45	9.91	0.545	2.315

NP Cost at 3%	119,084,283
NP Cost at 6%	94,243,602
NP Cost at 9%	80,855,306

Capital Cost :	60,485,117
Operation + Maintenance	359,101
Pumping Costs	2,686,651

OPTION 13

OPTION 13

COMPONENT	Waklyn Weir			Waklyn Pipeline				Waklyn Pipeline												
CAPACITY	1Mm³/a			600 mm diam				300 mm diam					FLOW (Mm³/a)					FLOW REQUIRED (Mm³/a)		
Year	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cost	TOTAL CASH FLOW	Bongola	Waklyn Weir Pipeline	Waklyn Weir Pipeline	Total Queenstown Supply	Total Queenstown Demand	Total Queenstown Requirement	Rural Req.	Sada
2003																		7.41	0.746	2.207
2004	47,005,250			35,292,476								**82,297,726**	1.35	6.92				7.52	0.749	2.213
2005		117,513	23,503		163,019	45,095	1,379,627					**1,728,757**	1.35	6.96		**8.31**	**8.31**	7.57	0.743	2.220
2006		117,513	23,503		163,019	45,095	1,391,882					**1,741,011**	1.35	7.03		**8.38**	**8.38**	7.64	0.739	2.227
2007		117,513	23,503		163,019	45,095	1,404,254					**1,753,384**	1.35	7.09		**8.44**	**8.44**	7.70	0.735	2.233
2008		117,513	23,503		163,019	45,095	1,416,746					**1,765,876**	1.35	7.15		**8.50**	**8.50**	7.77	0.731	2.240
2009		117,513	23,503		163,019	45,095	1,429,357					**1,778,487**	1.35	7.21		**8.56**	**8.56**	7.84	0.727	2.247
2010		117,513	23,503		163,019	45,095	1,442,089					**1,791,219**	1.35	7.28		**8.63**	**8.63**	7.91	0.723	2.253
2011		117,513	23,503		163,019	45,095	1,454,943					**1,804,072**	1.35	7.34		**8.69**	**8.69**	7.97	0.719	2.260
2012		117,513	23,503		163,019	45,095	1,467,919					**1,817,049**	1.35	7.41		**8.76**	**8.76**	8.04	0.715	2.267
2013		117,513	23,503		163,019	45,095	1,481,019					**1,830,149**	1.35	7.47		**8.82**	**8.82**	8.11	0.711	2.274
2014		117,513	23,503		163,019	45,095	1,494,244					**1,843,374**	1.35	7.54		**8.89**	**8.89**	8.18	0.707	2.281
2015		117,513	23,503		163,019	45,095	1,507,595					**1,856,724**	1.35	7.61		**8.96**	**8.96**	8.26	0.704	2.287
2016		117,513	23,503		163,019	45,095	1,516,387					**1,865,517**	1.35	7.65		**9.00**	**9.00**	8.31	0.698	2.294
2017		117,513	23,503		163,019	45,095	1,525,251					**1,874,381**	1.35	7.70		**9.05**	**9.05**	8.36	0.692	2.301
2018		117,513	23,503		163,019	45,095	1,534,186					**1,883,315**	1.35	7.74		**9.09**	**9.09**	8.41	0.686	2.308
2019		117,513	23,503		163,019	45,095	1,543,192	17,028,093				**18,920,415**	1.35	7.79		**9.14**	**9.14**	8.46	0.680	2.315
2020		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	0	**1,968,907**	1.35	7.83	0.00	**9.18**	**9.18**	8.51	0.674	2.315
2021		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	6,545	**1,975,452**	1.35	7.83	0.05	**9.23**	**9.23**	8.56	0.668	2.315
2022		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	13,142	**1,982,049**	1.35	7.83	0.09	**9.28**	**9.28**	8.61	0.663	2.315
2023		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	19,791	**1,988,697**	1.35	7.83	0.14	**9.32**	**9.32**	8.67	0.657	2.315
2024		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	26,492	**1,995,398**	1.35	7.83	0.19	**9.37**	**9.37**	8.72	0.652	2.315
2025		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	33,245	**2,002,152**	1.35	7.83	0.23	**9.42**	**9.42**	8.77	0.646	2.315
2026		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	40,051	**2,008,958**	1.35	7.83	0.28	**9.47**	**9.47**	8.83	0.641	2.315
2027		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	46,910	**2,015,817**	1.35	7.83	0.33	**9.52**	**9.52**	8.88	0.635	2.315
2028		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	53,822	**2,022,729**	1.35	7.83	0.38	**9.56**	**9.56**	8.93	0.630	2.315
2029		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	60,788	**2,029,695**	1.35	7.83	0.43	**9.61**	**9.61**	8.99	0.624	2.315
2030		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	67,807	**2,036,714**	1.35	7.83	0.48	**9.66**	**9.66**	9.04	0.619	2.315
2031		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	74,880	**2,043,786**	1.35	7.83	0.53	**9.71**	**9.71**	9.10	0.614	2.315
2032		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	82,006	**2,050,913**	1.35	7.83	0.58	**9.76**	**9.76**	9.15	0.609	2.315
2033		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	89,188	**2,058,094**	1.35	7.83	0.63	**9.81**	**9.81**	9.21	0.603	2.315
2034		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	96,423	**2,065,330**	1.35	7.83	0.68	**9.86**	**9.86**	9.27	0.598	2.315
2035		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	103,713	**2,072,620**	1.35	7.83	0.73	**9.92**	**9.92**	9.32	0.593	2.315
2036		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	111,059	**2,079,966**	1.35	7.83	0.78	**9.97**	**9.97**	9.38	0.588	2.315
2037		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	118,459	**2,087,366**	1.35	7.83	0.84	**10.02**	**10.02**	9.44	0.583	2.315
2038		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	125,916	**2,094,822**	1.35	7.83	0.89	**10.07**	**10.07**	9.49	0.578	2.315
2039		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	133,427	**2,102,334**	1.35	7.83	0.94	**10.13**	**10.13**	9.55	0.573	2.315
2040		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	140,995	**2,109,902**	1.35	7.83	0.99	**10.18**	**10.18**	9.61	0.568	2.315
2041		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	148,619	**2,117,526**	1.35	7.83	1.05	**10.23**	**10.23**	9.67	0.564	2.315
2042		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	156,300	**2,125,206**	1.35	7.83	1.10	**10.29**	**10.29**	9.73	0.559	2.315
2043		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	164,037	**2,132,944**	1.35	7.83	1.16	**10.34**	**10.34**	9.79	0.554	2.315
2044		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	171,831	**2,140,738**	1.35	7.83	1.21	**10.40**	**10.40**	9.85	0.549	2.315
2045		117,513	23,503		163,019	45,095	1,552,270		46,019	21,488	179,683	**2,148,590**	1.35	7.83	1.27	**10.45**	**10.45**	9.91	0.545	2.315

NP Cost at 3%	134,245,151
NP Cost at 6%	111,262,265
NP Cost at 9%	98,135,321

Capital Cost:	99,325,819
Operation + Maintenance	416,637
Pumping Costs	1,731,953

OPTION 14

OPTION 14

COMPONENT	Waterdown Dam Raising			New Waterdown Pipeline					Flow Mm^3/a				FLOW REQUIRED (Mm^3/a)		
CAPACITY	$1Mm^3/a$			500 mm diam											
YEAR	Raising	Maintenance Cost	Operation Cost	Construct Pipeline/Pump	Maintenance Cost	Operation Cost	Pumping Cos	TOTAL CASH FLOW	Bongola	new Waterdown Pipeline	**Total Queenstown Supply**	**Total Queenstown Demand**	Total Queenstown Requirement	Rural Req.	Sada
													7.29	0.740	2.200
2003	23,423,511							**23,423,511**					7.41	0.746	2.207
2004	23,423,511			70,902,324				**94,325,835**					7.52	0.749	2.213
2005		117,118	23,424		275,753	91,123	1,511,744	**2,019,161**	1.35	6.96	**8.31**	**8.31**	7.57	0.743	2.220
2006		117,118	23,424		275,753	91,123	1,525,173	**2,032,590**	1.35	7.03	**8.38**	**8.38**	7.64	0.739	2.227
2007		117,118	23,424		275,753	91,123	1,538,730	**2,046,147**	1.35	7.09	**8.44**	**8.44**	7.70	0.735	2.233
2008		117,118	23,424		275,753	91,123	1,552,418	**2,059,835**	1.35	7.15	**8.50**	**8.50**	7.77	0.731	2.240
2009		117,118	23,424		275,753	91,123	1,566,237	**2,073,654**	1.35	7.21	**8.56**	**8.56**	7.84	0.727	2.247
2010		117,118	23,424		275,753	91,123	1,580,188	**2,087,605**	1.35	7.28	**8.63**	**8.63**	7.91	0.723	2.253
2011		117,118	23,424		275,753	91,123	1,594,272	**2,101,689**	1.35	7.34	**8.69**	**8.69**	7.97	0.719	2.260
2012		117,118	23,424		275,753	91,123	1,608,491	**2,115,908**	1.35	7.41	**8.76**	**8.76**	8.04	0.715	2.267
2013		117,118	23,424		275,753	91,123	1,622,846	**2,130,263**	1.35	7.47	**8.82**	**8.82**	8.11	0.711	2.274
2014		117,118	23,424		275,753	91,123	1,637,337	**2,144,754**	1.35	7.54	**8.89**	**8.89**	8.18	0.707	2.281
2015		117,118	23,424		275,753	91,123	1,651,967	**2,159,384**	1.35	7.61	**8.96**	**8.96**	8.26	0.704	2.287
2016		117,118	23,424		275,753	91,123	1,661,601	**2,169,018**	1.35	7.65	**9.00**	**9.00**	8.31	0.698	2.294
2017		117,118	23,424		275,753	91,123	1,671,314	**2,178,731**	1.35	7.70	**9.05**	**9.05**	8.36	0.692	2.301
2018		117,118	23,424		275,753	91,123	1,681,104	**2,188,521**	1.35	7.74	**9.09**	**9.09**	8.41	0.686	2.308
2019		117,118	23,424		275,753	91,123	1,690,973	**2,198,390**	1.35	7.79	**9.14**	**9.14**	8.46	0.680	2.315
2020		117,118	23,424		275,753	91,123	1,700,920	**2,208,337**	1.35	7.83	**9.18**	**9.18**	8.51	0.674	2.315
2021		117,118	23,424		275,753	91,123	1,710,947	**2,218,364**	1.35	7.88	**9.23**	**9.23**	8.56	0.668	2.315
2022		117,118	23,424		275,753	91,123	1,721,052	**2,228,469**	1.35	7.93	**9.28**	**9.28**	8.61	0.663	2.315
2023		117,118	23,424		275,753	91,123	1,731,238	**2,238,655**	1.35	7.97	**9.32**	**9.32**	8.67	0.657	2.315
2024		117,118	23,424		275,753	91,123	1,741,503	**2,248,920**	1.35	8.02	**9.37**	**9.37**	8.72	0.652	2.315
2025		117,118	23,424		275,753	91,123	1,751,849	**2,259,266**	1.35	8.07	**9.42**	**9.42**	8.77	0.646	2.315
2026		117,118	23,424		275,753	91,123	1,762,275	**2,269,692**	1.35	8.12	**9.47**	**9.47**	8.83	0.641	2.315
2027		117,118	23,424		275,753	91,123	1,772,783	**2,280,200**	1.35	8.17	**9.52**	**9.52**	8.88	0.635	2.315
2028		117,118	23,424		275,753	91,123	1,783,371	**2,290,788**	1.35	8.21	**9.56**	**9.56**	8.93	0.630	2.315
2029		117,118	23,424		275,753	91,123	1,794,042	**2,301,459**	1.35	8.26	**9.61**	**9.61**	8.99	0.624	2.315
2030		117,118	23,424		275,753	91,123	1,804,794	**2,312,211**	1.35	8.31	**9.66**	**9.66**	9.04	0.619	2.315
2031		117,118	23,424		275,753	91,123	1,815,629	**2,323,046**	1.35	8.36	**9.71**	**9.71**	9.10	0.614	2.315
2032		117,118	23,424		275,753	91,123	1,826,547	**2,333,964**	1.35	8.41	**9.76**	**9.76**	9.15	0.609	2.315
2033		117,118	23,424		275,753	91,123	1,837,548	**2,344,965**	1.35	8.46	**9.81**	**9.81**	9.21	0.603	2.315
2034		117,118	23,424		275,753	91,123	1,848,632	**2,356,049**	1.35	8.51	**9.86**	**9.86**	9.27	0.598	2.315
2035		117,118	23,424		275,753	91,123	1,859,800	**2,367,217**	1.35	8.57	**9.92**	**9.92**	9.32	0.593	2.315
2036		117,118	23,424		275,753	91,123	1,871,053	**2,378,470**	1.35	8.62	**9.97**	**9.97**	9.38	0.588	2.315
2037		117,118	23,424		275,753	91,123	1,882,390	**2,389,807**	1.35	8.67	**10.02**	**10.02**	9.44	0.583	2.315
2038		117,118	23,424		275,753	91,123	1,893,812	**2,401,229**	1.35	8.72	**10.07**	**10.07**	9.49	0.578	2.315
2039		117,118	23,424		275,753	91,123	1,905,319	**2,412,736**	1.35	8.78	**10.13**	**10.13**	9.55	0.573	2.315
2040		117,118	23,424		275,753	91,123	1,916,912	**2,424,330**	1.35	8.83	**10.18**	**10.18**	9.61	0.568	2.315
2041		117,118	23,424		275,753	91,123	1,928,592	**2,436,009**	1.35	8.88	**10.23**	**10.23**	9.67	0.564	2.315
2042		117,118	23,424		275,753	91,123	1,940,358	**2,447,775**	1.35	8.94	**10.29**	**10.29**	9.73	0.559	2.315
2043		117,118	23,424		275,753	91,123	1,952,211	**2,459,628**	1.35	8.99	**10.34**	**10.34**	9.79	0.554	2.315
2044		117,118	23,424		275,753	91,123	1,964,151	**2,471,568**	1.35	9.05	**10.40**	**10.40**	9.85	0.549	2.315
2045		117,118	23,424		156,758	83,578	1,976,179	**2,357,056**	1.35	9.10	**10.45**	**10.45**	9.91	0.545	2.315

NP Cost at 3%	160,452,842
NP Cost at 6%	135,325,921
NP Cost at 9%	120,338,438

Capital Cost:	117,749,347
Operation + Maintenance	380,877
Pumping Costs	1,976,179

OPTION 15

COMPONENT	OPTION 15 Xonxa Pipeline				Waklyn Weir			Waklyn Weir Pipeline												
CAPACITY	500 mm diam				$1 Mm^3/a$			300 mm diam					FLOW (Mm^3/a)					FLOW REQUIRED (Mm^3/a)		
YEAR	Construct Pipeline/ Pump	Maintenance Cost	Operation Cost	Pumping Cost	Construct Weir	Maintenance Cost	Operation Cost	Construct Pipeline/ Pump	Maintenance Cost	Operation Cost	Pumping Cost	TOTAL CASH FLOW	Bongola	Xonxa Pipeline	Waklyn Weir Pipeline	Total Queenstown Supply	Total Queenstown Demand	Total Queenstown Requirement	Rural Req.	Sada
																		7.29	0.740	2.200
2003																		7.41	0.746	2.207
2004	53,011,019											**53,011,019**	1.35	6.92				7.52	0.749	2.213
2005		260,834	67,997	2,483,258								**2,812,089**	1.35	6.96		**8.31**	**8.31**	7.57	0.743	2.220
2006		260,834	67,997	2,505,316								**2,834,147**	1.35	7.03		**8.38**	**8.38**	7.64	0.739	2.227
2007		260,834	67,997	2,527,586								**2,856,417**	1.35	7.09		**8.44**	**8.44**	7.70	0.735	2.233
2008		260,834	67,997	2,550,070								**2,878,901**	1.35	7.15		**8.50**	**8.50**	7.77	0.731	2.240
2009		260,834	67,997	2,572,770								**2,901,601**	1.35	7.21		**8.56**	**8.56**	7.84	0.727	2.247
2010		260,834	67,997	2,595,687								**2,924,518**	1.35	7.28		**8.63**	**8.63**	7.91	0.723	2.253
2011		260,834	67,997	2,618,823								**2,947,654**	1.35	7.34		**8.69**	**8.69**	7.97	0.719	2.260
2012		260,834	67,997	2,642,179								**2,971,010**	1.35	7.41		**8.76**	**8.76**	8.04	0.715	2.267
2013		260,834	67,997	2,665,759								**2,994,590**	1.35	7.47		**8.82**	**8.82**	8.11	0.711	2.274
2014		260,834	67,997	2,689,563								**3,018,394**	1.35	7.54		**8.89**	**8.89**	8.18	0.707	2.281
2015		260,834	67,997	2,713,594								**3,042,425**	1.35	7.61		**8.96**	**8.96**	8.26	0.704	2.287
2016		260,834	67,997	2,729,420								**3,058,251**	1.35	7.65		**9.00**	**9.00**	8.31	0.698	2.294
2017		260,834	67,997	2,745,374								**3,074,205**	1.35	7.70		**9.05**	**9.05**	8.36	0.692	2.301
2018		260,834	67,997	2,761,456								**3,090,287**	1.35	7.74		**9.09**	**9.09**	8.41	0.686	2.308
2019		260,834	67,997	2,777,667	47,005,250			17,028,093				**67,139,841**	1.35	7.79		**9.14**	**9.14**	8.46	0.680	2.315
2020		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	0	**3,331,361**	1.35	7.83	0.00	**9.18**	**9.18**	8.51	0.674	2.315
2021		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	6,545	**3,337,906**	1.35	7.83	0.05	**9.23**	**9.23**	8.56	0.668	2.315
2022		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	13,142	**3,344,503**	1.35	7.83	0.09	**9.28**	**9.28**	8.61	0.663	2.315
2023		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	19,791	**3,351,151**	1.35	7.83	0.14	**9.32**	**9.32**	8.67	0.657	2.315
2024		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	26,492	**3,357,852**	1.35	7.83	0.19	**9.37**	**9.37**	8.72	0.652	2.315
2025		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	33,245	**3,364,606**	1.35	7.83	0.23	**9.42**	**9.42**	8.77	0.646	2.315
2026		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	40,051	**3,371,412**	1.35	7.83	0.28	**9.47**	**9.47**	8.83	0.641	2.315
2027		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	46,910	**3,378,271**	1.35	7.83	0.33	**9.52**	**9.52**	8.88	0.635	2.315
2028		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	53,822	**3,385,183**	1.35	7.83	0.38	**9.56**	**9.56**	8.93	0.630	2.315
2029		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	60,788	**3,392,149**	1.35	7.83	0.43	**9.61**	**9.61**	8.99	0.624	2.315
2030		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	67,807	**3,399,168**	1.35	7.83	0.48	**9.66**	**9.66**	9.04	0.619	2.315
2031		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	74,880	**3,406,240**	1.35	7.83	0.53	**9.71**	**9.71**	9.10	0.614	2.315
2032		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	82,006	**3,413,367**	1.35	7.83	0.58	**9.76**	**9.76**	9.15	0.609	2.315
2033		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	89,188	**3,420,548**	1.35	7.83	0.63	**9.81**	**9.81**	9.21	0.603	2.315
2034		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	96,423	**3,427,784**	1.35	7.83	0.68	**9.86**	**9.86**	9.27	0.598	2.315
2035		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	103,713	**3,435,074**	1.35	7.83	0.73	**9.92**	**9.92**	9.32	0.593	2.315
2036		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	111,059	**3,442,420**	1.35	7.83	0.78	**9.97**	**9.97**	9.38	0.588	2.315
2037		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	118,459	**3,449,820**	1.35	7.83	0.84	**10.02**	**10.02**	9.44	0.583	2.315
2038		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	125,916	**3,457,276**	1.35	7.83	0.89	**10.07**	**10.07**	9.49	0.578	2.315
2039		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	133,427	**3,464,788**	1.35	7.83	0.94	**10.13**	**10.13**	9.55	0.573	2.315
2040		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	140,995	**3,472,356**	1.35	7.83	0.99	**10.18**	**10.18**	9.61	0.568	2.315
2041		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	148,619	**3,479,980**	1.35	7.83	1.05	**10.23**	**10.23**	9.67	0.564	2.315
2042		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	156,300	**3,487,660**	1.35	7.83	1.10	**10.29**	**10.29**	9.73	0.559	2.315
2043		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	164,037	**3,495,398**	1.35	7.83	1.16	**10.34**	**10.34**	9.79	0.554	2.315
2044		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	171,831	**3,503,192**	1.35	7.83	1.21	**10.40**	**10.40**	9.85	0.549	2.315
2045		260,834	67,997	2,794,007		117,513	23,503		46,019	21,488	179,683	**3,511,044**	1.35	7.83	1.27	**10.45**	**10.45**	9.91	0.545	2.315

NP Cost at 3%	163,576,253
NP Cost at 6%	119,573,976
NP Cost at 9%	94,922,868

Capital Cost :	117,044,362
Operation + Maintenance	537,354
Pumping Costs	2,973,690

OPTION16

OPTION 16

COMPONENT CAPACITY	Xonxa Pipeline 500 mm diam				Xonxa Pipeline 200mm diam					Flow (Mm³/a)					FLOW REQUIRED (Mm³/a)		
	Construct Pipeline	Maintenance Cost	Operation Cost	Pumping Cost	Construct Pipeline	Maintenance Cost	Operation Cost	Pumping Cost	TOTAL CASH FLOW	Bongola	Xonxa Pipeline 1	Xonxa Pipeline 2	Total Queenstown Supply	Total Queenstown Demand	Total Queenstown Requirement	Rural Req.	Sada
YEAR															7.29	0.740	2.200
2003															7.41	0.746	2.207
2004	53,011,019								53,011,019	1.35	6.92				7.52	0.749	2.213
2005		260,834	67,997	2,483,258					2,812,089	1.35	6.96		8.31	8.31	7.57	0.743	2.220
2006		260,834	67,997	2,505,316					2,834,147	1.35	7.03		8.38	8.38	7.64	0.739	2.227
2007		260,834	67,997	2,527,586					2,856,417	1.35	7.09		8.44	8.44	7.70	0.735	2.233
2008		260,834	67,997	2,550,070					2,878,901	1.35	7.15		8.50	8.50	7.77	0.731	2.240
2009		260,834	67,997	2,572,770					2,901,601	1.35	7.21		8.56	8.56	7.84	0.727	2.247
2010		260,834	67,997	2,595,687					2,924,518	1.35	7.28		8.63	8.63	7.91	0.723	2.253
2011		260,834	67,997	2,618,823					2,947,654	1.35	7.34		8.69	8.69	7.97	0.719	2.260
2012		260,834	67,997	2,642,179					2,971,010	1.35	7.41		8.76	8.76	8.04	0.715	2.267
2013		260,834	67,997	2,665,759					2,994,590	1.35	7.47		8.82	8.82	8.11	0.711	2.274
2014		260,834	67,997	2,689,563					3,018,394	1.35	7.54		8.89	8.89	8.18	0.707	2.281
2015		260,834	67,997	2,713,594					3,042,425	1.35	7.61		8.96	8.96	8.26	0.704	2.287
2016		260,834	67,997	2,729,420					3,058,251	1.35	7.65		9.00	9.00	8.31	0.698	2.294
2017		260,834	67,997	2,745,374					3,074,205	1.35	7.70		9.05	9.05	8.36	0.692	2.301
2018		260,834	67,997	2,761,456					3,090,287	1.35	7.74		9.09	9.09	8.41	0.686	2.308
2019		260,834	67,997	2,777,667					3,106,498	1.35	7.79		9.14	9.14	8.46	0.680	2.315
2020		260,834	67,997	2,794,007	17,218,061				20,340,899	1.35	7.83	0.00	9.18	9.18	8.51	0.674	2.315
2021		260,834	67,997	2,794,007		60,261	21,733	16,850	3,221,682	1.35	7.83	0.05	9.23	9.23	8.56	0.668	2.315
2022		260,834	67,997	2,794,007		60,261	21,733	33,833	3,238,665	1.35	7.83	0.09	9.28	9.28	8.61	0.663	2.315
2023		260,834	67,997	2,794,007		60,261	21,733	50,950	3,255,782	1.35	7.83	0.14	9.32	9.32	8.67	0.657	2.315
2024		260,834	67,997	2,794,007		60,261	21,733	68,201	3,273,033	1.35	7.83	0.19	9.37	9.37	8.72	0.652	2.315
2025		260,834	67,997	2,794,007		60,261	21,733	85,587	3,290,419	1.35	7.83	0.23	9.42	9.42	8.77	0.646	2.315
2026		260,834	67,997	2,794,007		60,261	21,733	103,109	3,307,941	1.35	7.83	0.28	9.47	9.47	8.83	0.641	2.315
2027		260,834	67,997	2,794,007		60,261	21,733	120,767	3,325,599	1.35	7.83	0.33	9.52	9.52	8.88	0.635	2.315
2028		260,834	67,997	2,794,007		60,261	21,733	138,562	3,343,394	1.35	7.83	0.38	9.56	9.56	8.93	0.630	2.315
2029		260,834	67,997	2,794,007		60,261	21,733	156,494	3,361,326	1.35	7.83	0.43	9.61	9.61	8.99	0.624	2.315
2030		260,834	67,997	2,794,007		60,261	21,733	174,564	3,379,396	1.35	7.83	0.48	9.66	9.66	9.04	0.619	2.315
2031		260,834	67,997	2,794,007		60,261	21,733	192,773	3,397,605	1.35	7.83	0.53	9.71	9.71	9.10	0.614	2.315
2032		260,834	67,997	2,794,007		60,261	21,733	211,120	3,415,952	1.35	7.83	0.58	9.76	9.76	9.15	0.609	2.315
2033		260,834	67,997	2,794,007		60,261	21,733	229,607	3,434,439	1.35	7.83	0.63	9.81	9.81	9.21	0.603	2.315
2034		260,834	67,997	2,794,007		60,261	21,733	248,235	3,453,067	1.35	7.83	0.68	9.86	9.86	9.27	0.598	2.315
2035		260,834	67,997	2,794,007		60,261	21,733	267,004	3,471,836	1.35	7.83	0.73	9.92	9.92	9.32	0.593	2.315
2036		260,834	67,997	2,794,007		60,261	21,733	285,914	3,490,746	1.35	7.83	0.78	9.97	9.97	9.38	0.588	2.315
2037		260,834	67,997	2,794,007		60,261	21,733	304,966	3,509,798	1.35	7.83	0.84	10.02	10.02	9.44	0.583	2.315
2038		260,834	67,997	2,794,007		60,261	21,733	324,161	3,528,993	1.35	7.83	0.89	10.07	10.07	9.49	0.578	2.315
2039		260,834	67,997	2,794,007		60,261	21,733	343,500	3,548,332	1.35	7.83	0.94	10.13	10.13	9.55	0.573	2.315
2040		260,834	67,997	2,794,007		60,261	21,733	362,983	3,567,815	1.35	7.83	0.99	10.18	10.18	9.61	0.568	2.315
2041		260,834	67,997	2,794,007		60,261	21,733	382,610	3,587,442	1.35	7.83	1.05	10.23	10.23	9.67	0.564	2.315
2042		260,834	67,997	2,794,007		60,261	21,733	402,383	3,607,215	1.35	7.83	1.10	10.29	10.29	9.73	0.559	2.315
2043		260,834	67,997	2,794,007		60,261	21,733	422,302	3,627,134	1.35	7.83	1.16	10.34	10.34	9.79	0.554	2.315
2044		260,834	67,997	2,794,007		60,261	21,733	442,369	3,647,201	1.35	7.83	1.21	10.40	10.40	9.85	0.549	2.315
2045		260,834	67,997	2,794,007		60,261	21,733	462,582	3,667,414	1.35	7.83	1.27	10.45	10.45	9.91	0.545	2.315

NP Cost at 3%	133,951,903
NP Cost at 6%	100,603,652
NP Cost at 9%	82,655,118

Capital Cost :	70,229,080
Operation + Maintenance	410,825
Pumping Costs	3,256,589

ADDENDUM 6.3

Calculation of Net Present Values for Final Comparison of Augmentation Schemes

OPTION A

COMPONENT CAPACITY	Second Waterdown Pipeline 400 mm diameter 3.7 Mm^3/a				Xonxa Pipeline 300 mm diameter 1.1 Mm^3/a				Second Xonxa Pipeline 300 mm diameter 1.8 Mm^3/a					WATER SUPPLIED (Mm^3/a)					QUEENSTOWN SCHEME (Mm^3/a)	
	-Construct Pipeline/ Pump Stn.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	Construct Pipeline/ Pump Stns.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	Construct Pipeline/ Pump Stns.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	TOTAL CASH FLOW	Waterdown Pipeline (Existing) Queenstown Allocation	Bongola	Second Waterdown Pipeline	First Xonxa Pipeline	Second Xonxa Pipeline	Total Queenstown Requirement	Total Queenstown Supply Capacity
YEAR	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million							
2003																				5.90
2004	79.85				47.33								127.18	5.00	0.90					5.90
2005		0.31	0.43	0.32		0.18	0.34	0.12					1.70	5.00	0.90	3.70	0.50		10.10	10.70
2006		0.31	0.43	0.32		0.18	0.34	0.13					1.71	5.00	0.90	3.70	0.54		10.14	10.70
2007		0.31	0.43	0.32		0.18	0.34	0.13					1.71	5.00	0.90	3.70	0.58		10.18	10.70
2008		0.31	0.43	0.32		0.18	0.34	0.15					1.73	5.00	0.90	3.70	0.63		10.23	10.70
2009		0.31	0.43	0.32		0.18	0.34	0.16					1.74	5.00	0.90	3.70	0.68		10.28	10.70
2010		0.31	0.43	0.32		0.18	0.34	0.17					1.75	5.00	0.90	3.70	0.74		10.34	10.70
2011		0.31	0.43	0.32		0.18	0.34	0.19					1.77	5.00	0.90	3.70	0.80		10.40	10.70
2012		0.31	0.43	0.32		0.18	0.34	0.20					1.78	5.00	0.90	3.70	0.87		10.47	10.70
2013		0.31	0.43	0.32		0.18	0.34	0.22					1.80	5.00	0.90	3.70	0.94		10.54	10.70
2014		0.31	0.43	0.32		0.18	0.34	0.24					1.82	5.00	0.90	3.70	1.02		10.62	10.70
2015		0.31	0.43	0.32		0.18	0.34	0.26	47.80				49.64	5.00	0.90	3.70	1.10		10.70	12.50
2016		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.01	2.70	5.00	0.90	3.70	1.10	0.03	10.73	12.50
2017		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.02	2.71	5.00	0.90	3.70	1.10	0.05	10.75	12.50
2018		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.04	2.73	5.00	0.90	3.70	1.10	0.09	10.79	12.50
2019		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.06	2.75	5.00	0.90	3.70	1.10	0.16	10.86	12.50
2020		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.08	2.77	5.00	0.90	3.70	1.10	0.30	11.00	12.50
2021		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.09	2.78	5.00	0.90	3.70	1.10	0.33	11.03	12.50
2022		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.10	2.79	5.00	0.90	3.70	1.10	0.37	11.07	12.50
2023		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.11	2.80	5.00	0.90	3.70	1.10	0.41	11.11	12.50
2024		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.12	2.81	5.00	0.90	3.70	1.10	0.46	11.16	12.50
2025		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.14	2.83	5.00	0.90	3.70	1.10	0.52	11.22	12.50
2026		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.16	2.85	5.00	0.90	3.70	1.10	0.58	11.28	12.50
2027		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.18	2.87	5.00	0.90	3.70	1.10	0.65	11.35	12.50
2028		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.20	2.89	5.00	0.90	3.70	1.10	0.72	11.42	12.50
2029		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.22	2.91	5.00	0.90	3.70	1.10	0.80	11.50	12.50
2030		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.25	2.94	5.00	0.90	3.70	1.10	0.90	11.60	12.50
2031		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.26	2.95	5.00	0.90	3.70	1.10	0.94	11.64	12.50
2032		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.27	2.96	5.00	0.90	3.70	1.10	0.99	11.69	12.50
2033		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.28	2.97	5.00	0.90	3.70	1.10	1.03	11.73	12.50
2034		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.30	2.99	5.00	0.90	3.70	1.10	1.08	11.78	12.50
2035		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.31	3.00	5.00	0.90	3.70	1.10	1.13	11.83	12.50
2036		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.33	3.02	5.00	0.90	3.70	1.10	1.19	11.89	12.50
2037		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.34	3.03	5.00	0.90	3.70	1.10	1.24	11.94	12.50
2038		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.36	3.05	5.00	0.90	3.70	1.10	1.30	12.00	12.50
2039		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.38	3.07	5.00	0.90	3.70	1.10	1.36	12.06	12.50
2040		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.40	3.09	5.00	0.90	3.70	1.10	1.43	12.13	12.50
2041		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.42	3.11	5.00	0.90	3.70	1.10	1.50	12.20	12.50
2042		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.43	3.12	5.00	0.90	3.70	1.10	1.57	12.27	12.50
2043		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.45	3.14	5.00	0.90	3.70	1.10	1.64	12.34	12.50
2044		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.47	3.16	5.00	0.90	3.70	1.10	1.72	12.42	12.50
2045		0.31	0.43	0.32		0.18	0.34	0.26		0.19	0.66	0.50	3.19	5.00	0.90	3.70	1.10	1.80	12.50	12.50

NPCOST AT 3%	213
NPCOST AT 6%	176
NPCOST AT9%	155

Capital Cost :	175
Operation + Maintenance	2.11
Pumping Costs	0.76

OPTION B

COMPONENT CAPACITY	Second Waterdown Pipeline 400 mm diameter 3.7 Mm³/a				Xonxa Pipeline 400/300 mm diameter 1.1 Mm³/a (for later boosting)				Xonxa Pipeline Boosted to 2.1 Mm³/a 400/300 mm diameter 2.1 Mm³/a				Xonxa Pipeline Boosted to 2.8 Mm³/a 400/300 mm diameter 2.8 Mm³/a					WATER SUPPLIED (Mm3/a)						QUEENSTOWN SCHEME (Mm3/a)	
	Construct Pipeline/ Pump St.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	Construct Pipeline/ Pump Stns	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	Construct Pump Stns	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	Construct Pump Stns.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	TOTAL CASH FLOW	Waterdown Pipeline (Existing) Queenstown Allocation	Bongola	Second Waterdown Pipeline	First Xonxa Pipeline	Boosted Xonxa Pipeline	Further Boosted Xonxa Pipeline	Total Queenstown Requirement	Total Queenstown Supply Capacity
YEAR	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million								
2003																									5.90
2004	79.85				50.95												130.80	5.00	0.90						5.90
2005		0.31	0.43	0.32		0.19	0.34	0.12									1.71	5.00	0.90	3.70	0.50			10.10	10.70
2006		0.31	0.43	0.32		0.19	0.34	0.13									1.72	5.00	0.90	3.70	0.54			10.14	10.70
2007		0.31	0.43	0.32		0.19	0.34	0.13									1.72	5.00	0.90	3.70	0.58			10.18	10.70
2008		0.31	0.43	0.32		0.19	0.34	0.15									1.74	5.00	0.90	3.70	0.63			10.23	10.70
2009		0.31	0.43	0.32		0.19	0.34	0.16									1.75	5.00	0.90	3.70	0.68			10.28	10.70
2010		0.31	0.43	0.32		0.19	0.34	0.17									1.76	5.00	0.90	3.70	0.74			10.34	10.70
2011		0.31	0.43	0.32		0.19	0.34	0.19									1.78	5.00	0.90	3.70	0.80			10.40	10.70
2012		0.31	0.43	0.32		0.19	0.34	0.20									1.79	5.00	0.90	3.70	0.87			10.47	10.70
2013		0.31	0.43	0.32		0.19	0.34	0.22									1.81	5.00	0.90	3.70	0.94			10.54	10.70
2014		0.31	0.43	0.32		0.19	0.34	0.24									1.83	5.00	0.90	3.70	1.02			10.62	10.70
2015		0.31	0.43	0.32		0.19	0.34	0.26	1.42								3.27	5.00	0.90	3.70	1.10			10.70	10.70
2016		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.01					2.34	5.00	0.90	3.70	1.10	0.03		10.73	11.70
2017		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.02					2.35	5.00	0.90	3.70	1.10	0.05		10.75	11.70
2018		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.03					2.36	5.00	0.90	3.70	1.10	0.09		10.79	11.70
2019		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.05					2.38	5.00	0.90	3.70	1.10	0.16		10.86	11.70
2020		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.10					2.43	5.00	0.90	3.70	1.10	0.30		11.00	11.70
2021		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.11					2.44	5.00	0.90	3.70	1.10	0.33		11.03	11.70
2022		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.12					2.45	5.00	0.90	3.70	1.10	0.37		11.07	11.70
2023		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.14					2.47	5.00	0.90	3.70	1.10	0.41		11.11	11.70
2024		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.15					2.48	5.00	0.90	3.70	1.10	0.46		11.16	11.70
2025		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.18					2.51	5.00	0.90	3.70	1.10	0.52		11.22	11.70
2026		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.20					2.53	5.00	0.90	3.70	1.10	0.58		11.28	11.70
2027		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.22					2.55	5.00	0.90	3.70	1.10	0.65		11.35	11.70
2028		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.24					2.57	5.00	0.90	3.70	1.10	0.72		11.42	11.70
2029		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.27					2.60	5.00	0.90	3.70	1.10	0.80		11.50	11.70
2030		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.30					2.63	5.00	0.90	3.70	1.10	0.90		11.60	11.70
2031		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.32	1.58				4.23	5.00	0.90	3.70	1.10	0.94		11.64	11.70
2032		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.05	3.31	5.00	0.90	3.70	1.10	0.99	0.10	11.80	12.50
2033		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.06	3.32	5.00	0.90	3.70	1.10	1.03	0.12	11.82	12.50
2034		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.07	3.33	5.00	0.90	3.70	1.10	1.08	0.14	11.84	12.50
2035		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.08	3.34	5.00	0.90	3.70	1.10	1.13	0.16	11.86	12.50
2036		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.09	3.35	5.00	0.90	3.70	1.10	1.19	0.19	11.89	12.50
2037		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.11	3.37	5.00	0.90	3.70	1.10	1.24	0.22	11.92	12.50
2038		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.13	3.39	5.00	0.90	3.70	1.10	1.30	0.260	11.96	12.50
2039		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.15	3.41	5.00	0.90	3.70	1.10	1.36	0.31	12.01	12.50
2040		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.18	3.44	5.00	0.90	3.70	1.10	1.43	0.36	12.06	12.50
2041		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.22	3.48	5.00	0.90	3.70	1.10	1.50	0.43	12.13	12.50
2042		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.25	3.51	5.00	0.90	3.70	1.10	1.57	0.50	12.20	12.50
2043		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.30	3.56	5.00	0.90	3.70	1.10	1.64	0.59	12.29	12.50
2044		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.35	3.61	5.00	0.90	3.70	1.10	1.72	0.69	12.39	12.50
2045		0.31	0.43	0.32		0.19	0.34	0.26		0.04	0.44	0.34		0.06	0.53	0.41	3.67	5.00	0.90	3.70	1.10	1.80	0.80	12.50	12.50

NP Cost at 3%	183
NP Cost at 6%	156
NP Cost at9%	141

Capital Cost :	133.8
Operation + Maintenance + kVA	2.3
Pumping Costs	1.3
URV (at 6%)	1.0

OPTION C

COMPONENT CAPACITY	Existing Waterdown Pipeline Boosted by 1.15 Mm³/a 450 mm diameter 6.15 Mm³/a				Groundwater to Sada Wellfields T3, T4 & T6 Yield 3.0 Mm³/a			Second Waterdown Pipeline 400/500 mm diameter 3.65 Mm³/a (for future boosting)				Second Waterdown Pipeline Boosted to 4.65 Mm³/a				Second Waterdown Pipeline Boosted to 5.4 Mm³/a				TOTAL CASH FLOW	WATER SUPPLIED (Mm3/a)						QUEENSTOWN SCHEME (Mm3/a)	
	Construct Pipeline/ Pump St.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	Construct Pipeline/ Pump Stns	Operation and Maintenance Cost	Electricity kVa Cost	Construct Pump Stns	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	Construct Pump Stns.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	Construct Pump Stns	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost		Waterdown Pipeline (Existing) Queenstown Allocation	Bongola	Second Waterdown Pipeline	First Xonxa Pipeline	Boosted Xonxa Pipeline	Further Boosted Xonxa Pipeline	Total Queenstown Requirement	Total Queenstown Supply Capacity
YEAR	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million					R million								
2003																												5.90
2004	0.35							90.58												90.93	5.00	0.90						5.90
2005		0.01	0.10	0.07					0.36	0.39	0.24									1.17	5.00	0.90	1.15	3.05			10.10	10.70
2006		0.01	0.10	0.07					0.36	0.39	0.24									1.17	5.00	0.90	1.15	3.09			10.14	10.70
2007		0.01	0.10	0.07	10.85				0.36	0.39	0.24									12.02	5.00	0.90	1.15	3.13			10.18	10.70
2008		0.01	0.10	0.07		0.03	0.17		0.36	0.39	0.25									1.38	5.00	0.90	1.15	3.18			10.23	10.70
2009		0.01	0.10	0.07		0.03	0.17		0.36	0.39	0.25									1.38	5.00	0.90	1.15	3.23			10.28	10.70
2010		0.01	0.10	0.07		0.03	0.18		0.36	0.39	0.26									1.40	5.00	0.90	1.15	3.29			10.34	10.70
2011		0.01	0.10	0.07		0.03	0.19		0.36	0.39	0.26									1.41	5.00	0.90	1.15	3.35			10.40	10.70
2012		0.01	0.10	0.07		0.03	0.19		0.36	0.39	0.27									1.42	5.00	0.90	1.15	3.42			10.47	10.70
2013		0.01	0.10	0.07		0.03	0.20		0.36	0.39	0.27									1.43	5.00	0.90	1.15	3.49			10.54	10.70
2014		0.01	0.10	0.07		0.03	0.21		0.36	0.39	0.28									1.45	5.00	0.90	1.15	3.57			10.62	10.70
2015		0.01	0.10	0.07		0.03	0.22		0.36	0.39	0.29	1.62								3.09	5.00	0.90	1.15	3.65			10.70	10.70
2016		0.01	0.10	0.07		0.03	0.23		0.36	0.39	0.29		0.04	0.46	0.01					1.99	5.00	0.90	1.15	3.65	0.03		10.73	12.00
2017		0.01	0.10	0.07		0.03	0.24		0.36	0.39	0.29		0.04	0.46	0.01					2.00	5.00	0.90	1.15	3.65	0.05		10.75	12.00
2018		0.01	0.10	0.07		0.03	0.25		0.36	0.39	0.29		0.04	0.46	0.01					2.01	5.00	0.90	1.15	3.65	0.09		10.79	12.00
2019		0.01	0.10	0.07		0.03	0.27		0.36	0.39	0.29		0.04	0.46	0.02					2.04	5.00	0.90	1.15	3.65	0.16		10.86	12.00
2020		0.01	0.10	0.07		0.03	0.29		0.36	0.39	0.29		0.04	0.46	0.02					2.06	5.00	0.90	1.15	3.65	0.30		11.00	12.00
2021		0.01	0.10	0.07		0.03	0.31		0.36	0.39	0.29		0.04	0.46	0.03					2.09	5.00	0.90	1.15	3.65	0.33		11.03	12.00
2022		0.01	0.10	0.07	10.00	0.03	0.34		0.36	0.39	0.29		0.04	0.46	0.04					12.13	5.00	0.90	1.15	3.65	0.37		11.07	12.00
2023		0.01	0.10	0.07		0.06	0.51		0.36	0.39	0.29		0.04	0.46	0.05					2.34	5.00	0.90	1.15	3.65	0.41		11.11	12.00
2024		0.01	0.10	0.07		0.06	0.52		0.36	0.39	0.29		0.04	0.46	0.06					2.36	5.00	0.90	1.15	3.65	0.46		11.16	12.00
2025		0.01	0.10	0.07		0.06	0.53		0.36	0.39	0.29		0.04	0.46	0.07					2.38	5.00	0.90	1.15	3.65	0.52		11.22	12.00
2026		0.01	0.10	0.07		0.06	0.53		0.36	0.39	0.29		0.04	0.46	0.09					2.40	5.00	0.90	1.15	3.65	0.58		11.28	12.00
2027		0.01	0.10	0.07		0.06	0.54		0.36	0.39	0.29		0.04	0.46	0.12					2.44	5.00	0.90	1.15	3.65	0.65		11.35	12.00
2028		0.01	0.10	0.07		0.06	0.55		0.36	0.39	0.29		0.04	0.46	0.15					2.48	5.00	0.90	1.15	3.65	0.72		11.42	12.00
2029		0.01	0.10	0.07		0.06	0.56		0.36	0.39	0.29		0.04	0.46	0.18					2.52	5.00	0.90	1.15	3.65	0.80		11.50	12.00
2030		0.01	0.10	0.07		0.06	0.57		0.36	0.39	0.29		0.04	0.46	0.23					2.58	5.00	0.90	1.15	3.65	0.90		11.60	12.00
2031		0.01	0.10	0.07		0.06	0.58		0.36	0.39	0.29		0.04	0.46	0.29					2.65	5.00	0.90	1.15	3.65	0.94		11.64	12.00
2032		0.01	0.10	0.07		0.06	0.59		0.36	0.39	0.29		0.04	0.46	0.36	1.54				4.27	5.00	0.90	1.15	3.65	1.00		11.70	12.50
2033		0.01	0.10	0.07		0.06	0.60		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.03	3.32	5.00	0.90	1.15	3.65	1.00	0.06	11.76	12.50
2034		0.01	0.10	0.07		0.06	0.61		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.04	3.34	5.00	0.90	1.15	3.65	1.00	0.12	11.82	12.50
2035		0.01	0.10	0.07		0.06	0.62		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.05	3.36	0.05	0.90	1.15	3.65	1.00	0.18	11.88	12.50
2036		0.01	0.10	0.07		0.06	0.63		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.06	3.38	5.00	0.06	1.15	3.65	1.00	0.24	11.94	12.50
2037		0.01	0.10	0.07		0.06	0.64		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.07	3.40	5.00	0.90	1.15	3.65	1.00	0.30	12.00	12.50
2038		0.01	0.10	0.07		0.06	0.65		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.09	3.43	5.00	0.90	1.15	3.65	1.00	0.36	12.06	12.50
2039		0.01	0.10	0.07		0.06	0.66		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.11	3.46	5.00	0.90	1.15	3.65	1.00	0.42	12.12	12.50
2040		0.01	0.10	0.07	7.35	0.06	0.67		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.13	10.84	5.00	0.90	1.15	3.65	1.00	0.49	12.19	12.50
2041		0.01	0.10	0.07		0.06	0.68		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.17	3.56	5.00	0.90	1.15	3.65	1.00	0.55	12.25	12.50
2042		0.01	0.10	0.07		0.08	0.69		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.21	3.61	5.00	0.90	1.15	3.65	1.00	0.61	12..31	12.50
2043		0.01	0.10	0.07		0.08	0.72		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.26	3.69	5.00	0.90	1.15	3.65	1.00	0.67	12.37	12.50
2044		0.01	0.10	0.07		0.08	0.74		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.32	3.77	5.00	0.90	1.15	3.65	1.00	0.74	12.44	12.50
2045		0.01	0.10	0.07		0.08	0.77		0.36	0.39	0.29		0.04	0.46	0.36		0.02	0.53	0.40	3.88	5.00	0.90	1.15	3.65	1.00	0.80	12.50	12.50

NP Cost at 3%	157
NP Cost at 6%	127
NP Cost at9%	111

Capital Cost :	111.4
Operation + Maintenance + kVA	
kVA	2.8
URV (at 6%)	0.78

OPTION D

COMPONENT CAPACITY	Xonxa Pipeline 400 mm diameter 4.8 Mm^3/a				Second Xonxa Pipeline 300 mm diameter 1.8 Mm^3/a				TOTAL CASH FLOW	WATER SUPPLIED (Mm^3/a)				QUEENSTOWN SCHEME (Mm3/a)	
	Construct Pipeline/ Pump Stn.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	Construct Pipeline/ Pump Stns.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost		Waterdown Pipeline (Existing) Queenstown Allocation	Bongola	First Xonxa Pipeline	Second Xonxa Pipeline	**Total Queenstown Requirement**	**Total Queenstown Supply Capacity**
YEAR	R million	R million	R million	R million	R million	R million	R million	R million	R million						
2003															**5.90**
2004	67.35								67.35	5.00	0.90				**5.90**
2005		0.36	1.94	1.32					3.62	5.00	0.90	4.20		**10.10**	**10.70**
2006		0.36	1.94	1.34					3.64	5.00	0.90	4.24		**10.14**	**10.70**
2007		0.36	1.94	1.35					3.65	5.00	0.90	4.28		**10.18**	**10.70**
2008		0.36	1.94	1.37					3.67	5.00	0.90	4.33		**10.23**	**10.70**
2009		0.36	1.94	1.39					3.69	5.00	0.90	4.38		**10.28**	**10.70**
2010		0.36	1.94	1.40					3.70	5.00	0.90	4.44		**10.34**	**10.70**
2011		0.36	1.94	1.42					3.72	5.00	0.90	4.50		**10.40**	**10.70**
2012		0.36	1.94	1.44					3.74	5.00	0.90	4.57		**10.47**	**10.70**
2013		0.36	1.94	1.46					3.76	5.00	0.90	4.64		**10.54**	**10.70**
2014		0.36	1.94	1.48					3.78	5.00	0.90	4.72		**10.62**	**10.70**
2015		0.36	1.94	1.50	47.80				51.60	5.00	0.90	4.80		**10.70**	**12.50**
2016		0.36	1.94	1.50		0.20	0.66	0.01	4.67	5.00	0.90	4.80	0.03	**10.73**	**12.50**
2017		0.36	1.94	1.50		0.20	0.66	0.02	4.68	5.00	0.90	4.80	0.05	**10.75**	**12.50**
2018		0.36	1.94	1.50		0.20	0.66	0.04	4.70	5.00	0.90	4.80	0.09	**10.79**	**12.50**
2019		0.36	1.94	1.50		0.20	0.66	0.06	4.72	5.00	0.90	4.80	0.16	**10.86**	**12.50**
2020		0.36	1.94	1.50		0.20	0.66	0.08	4.74	5.00	0.90	4.80	0.30	**11.00**	**12.50**
2021		0.36	1.94	1.50		0.20	0.66	0.09	4.75	5.00	0.90	4.80	0.33	**11.03**	**12.50**
2022		0.36	1.94	1.50		0.20	0.66	0.10	4.76	5.00	0.90	4.80	0.37	**11.07**	**12.50**
2023		0.36	1.94	1.50		0.20	0.66	0.11	4.77	5.00	0.90	4.80	0.41	**11.11**	**12.50**
2024		0.36	1.94	1.50		0.20	0.66	0.12	4.78	5.00	0.90	4.80	0.46	**11.16**	**12.50**
2025		0.36	1.94	1.50		0.20	0.66	0.14	4.80	5.00	0.90	4.80	0.52	**11.22**	**12.50**
2026		0.36	1.94	1.50		0.20	0.66	0.16	4.82	5.00	0.90	4.80	0.58	**11.28**	**12.50**
2027		0.36	1.94	1.50		0.20	0.66	0.18	4.84	5.00	0.90	4.80	0.65	**11.35**	**12.50**
2028		0.36	1.94	1.50		0.20	0.66	0.20	4.86	5.00	0.90	4.80	0.72	**11.42**	**12.50**
2029		0.36	1.94	1.50		0.20	0.66	0.22	4.88	5.00	0.90	4.80	0.80	**11.50**	**12.50**
2030		0.36	1.94	1.50		0.20	0.66	0.25	4.91	5.00	0.90	4.80	0.90	**11.60**	**12.50**
2031		0.36	1.94	1.50		0.20	0.66	0.26	4.92	5.00	0.90	4.80	0.94	**11.64**	**12.50**
2032		0.36	1.94	1.50		0.20	0.66	0.27	4.93	5.00	0.90	4.80	0.99	**11.69**	**12.50**
2033		0.36	1.94	1.50		0.20	0.66	0.28	4.94	5.00	0.90	4.80	1.03	**11.73**	**12.50**
2034		0.36	1.94	1.50		0.20	0.66	0.30	4.96	5.00	0.90	4.80	1.08	**11.78**	**12.50**
2035		0.36	1.94	1.50		0.20	0.66	0.31	4.97	5.00	0.90	4.80	1.13	**11.83**	**12.50**
2036		0.36	1.94	1.50		0.20	0.66	0.33	4.99	5.00	0.90	4.80	1.19	**11.89**	**12.50**
2037		0.36	1.94	1.50		0.20	0.66	0.34	5.00	5.00	0.90	4.80	1.24	**11.94**	**12.50**
2038		0.36	1.94	1.50		0.20	0.66	0.36	5.02	5.00	0.90	4.80	1.30	**12.00**	**12.50**
2039		0.36	1.94	1.50		0.20	0.66	0.38	5.04	5.00	0.90	4.80	1.36	**12.06**	**12.50**
2040		0.36	1.94	1.50		0.20	0.66	0.40	5.06	5.00	0.90	4.80	1.43	**12.13**	**12.50**
2041		0.36	1.94	1.50		0.20	0.66	0.42	5.08	5.00	0.90	4.80	1.50	**12.20**	**12.50**
2042		0.36	1.94	1.50		0.20	0.66	0.43	5.09	5.00	0.90	4.80	1.57	**12.27**	**12.50**
2043		0.36	1.94	1.50		0.20	0.66	0.45	5.11	5.00	0.90	4.80	1.64	**12.34**	**12.50**
2044		0.36	1.94	1.50		0.20	0.66	0.47	5.13	5.00	0.90	4.80	1.72	**12.42**	**12.50**
2045		0.36	1.94	1.50		0.20	0.66	0.50	5.16	5.00	0.90	4.80	1.80	**12.50**	**12.50**

NP COST AT 3%	199
NP COST AT 6%	148
NP COST AT9%	119

Capital Cost :	115
Operation + Maintenance	0.6
Pumping Costs	4.6
URV (at 6%)	0.90

OPTION E

COMPONENT CAPACITY	Xonxa Pipeline 400 mm diameter 4.8 Mm^3/a				Xonxa Pipeline Boosted 400 mm diameter 5.8 Mm^3/a				Xonxa Pipeline Further Boosted 400 mm diameter 6.4 Mm^3/a					WATER SUPPLIED (Mm^3/a)					QUEENSTOWN SCHEME (Mm^3/a)	
	Construct Pipeline/ Pump Stn.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	Construct Pipeline/ Pump Stns.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	Construct Pipeline/ Pump Stns.	Operation and Maintenance Cost	Electricity kVa Cost	Electric Energy Cost	**TOTAL CASH FLOW**	Waterdown Pipeline (Existing) Queenstown Allocation	Bongola	First Xonxa Pipeline	Xonxa Pipeline Boosted	Second Xonxa Pipeline	**Total Queenstown Requirement**	**Total Queenstown Supply Capacity**
YEAR	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million	R million							
2003																				**5.90**
2004	68.00												68.00	5.00	0.90					**5.90**
2005		0.35	1.81	1.22									3.38	5.00	0.90	4.20			**10.10**	**10.70**
2006		0.35	1.81	1.24									3.40	5.00	0.90	4.24			**10.14**	**10.70**
2007		0.35	1.81	1.25									3.41	5.00	0.90	4.28			**10.18**	**10.70**
2008		0.35	1.81	1.27									3.43	5.00	0.90	4.33			**10.23**	**10.70**
2009		0.35	1.81	1.29									3.45	5.00	0.90	4.38			**10.28**	**10.70**
2010		0.35	1.81	1.30									3.46	5.00	0.90	4.44			**10.34**	**10.70**
2011		0.35	1.81	1.32									3.48	5.00	0.90	4.50			**10.40**	**10.70**
2012		0.35	1.81	1.34									3.50	5.00	0.90	4.57			**10.47**	**10.70**
2013		0.35	1.81	1.35									3.51	5.00	0.90	4.64			**10.54**	**10.70**
2014		0.35	1.81	1.37									3.53	5.00	0.90	4.72			**10.62**	**10.70**
2015		0.35	1.81	1.39	1.37								4.92	5.00	0.90	4.80			**10.70**	**12.50**
2016		0.35	1.81	1.39		0.04	0.62	0.01					4.22	5.00	0.90	4.80	0.03		**10.73**	**12.50**
2017		0.35	1.81	1.39		0.04	0.62	0.01					4.22	5.00	0.90	4.80	0.05		**10.75**	**12.50**
2018		0.35	1.81	1.39		0.04	0.62	0.03					4.24	5.00	0.90	4.80	0.09		**10.79**	**12.50**
2019		0.35	1.81	1.39		0.04	0.62	0.03					4.24	5.00	0.90	4.80	0.16		**10.86**	**12.50**
2020		0.35	1.81	1.39		0.04	0.62	0.03					4.24	5.00	0.90	4.80	0.30		**11.00**	**12.50**
2021		0.35	1.81	1.39		0.04	0.62	0.04					4.25	5.00	0.90	4.80	0.33		**11.03**	**12.50**
2022		0.35	1.81	1.39		0.04	0.62	0.04					4.25	5.00	0.90	4.80	0.37		**11.07**	**12.50**
2023		0.35	1.81	1.39		0.04	0.62	0.06					4.27	5.00	0.90	4.80	0.41		**11.11**	**12.50**
2024		0.35	1.81	1.39		0.04	0.62	0.07					4.28	5.00	0.90	4.80	0.46		**11.16**	**12.50**
2025		0.35	1.81	1.39		0.04	0.62	0.09					4.30	5.00	0.90	4.80	0.52		**11.22**	**12.50**
2026		0.35	1.81	1.39		0.04	0.62	0.11					4.32	5.00	0.90	4.80	0.58		**11.28**	**12.50**
2027		0.35	1.81	1.39		0.04	0.62	0.14					4.35	5.00	0.90	4.80	0.65		**11.35**	**12.50**
2028		0.35	1.81	1.39		0.04	0.62	0.17					4.38	5.00	0.90	4.80	0.72		**11.42**	**12.50**
2029		0.35	1.81	1.39		0.04	0.62	0.22					4.43	5.00	0.90	4.80	0.80		**11.50**	**12.50**
2030		0.35	1.81	1.39		0.04	0.62	0.26					4.47	5.00	0.90	4.80	0.90		**11.60**	**12.50**
2031		0.35	1.81	1.39		0.04	0.62	0.32					4.53	5.00	0.90	4.80	0.94		**11.64**	**12.50**
2032		0.35	1.81	1.39		0.04	0.62	0.39	1.50				6.10	5.00	0.90	4.80	0.99		**11.69**	**11.70**
2033		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.02	5.19	5.00	0.90	4.80	1.00	0.03	**11.73**	**12.50**
2034		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.03	5.20	5.00	0.90	4.80	1.00	0.08	**11.78**	**12.50**
2035		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.03	5.20	5.00	0.90	4.80	1.00	0.13	**11.83**	**12.50**
2036		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.04	5.21	5.00	0.90	4.80	1.00	0.19	**11.89**	**12.50**
2037		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.05	5.22	5.00	0.90	4.80	1.00	0.24	**11.94**	**12.50**
2038		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.07	5.24	5.00	0.90	4.80	1.00	0.30	**12.00**	**12.50**
2039		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.09	5.26	5.00	0.90	4.80	1.00	0.36	**12.06**	**12.50**
2040		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.11	5.28	5.00	0.90	4.80	1.00	0.43	**12.13**	**12.50**
2041		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.14	5.31	5.00	0.90	4.80	1.00	0.50	**12.20**	**12.50**
2042		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.18	5.35	5.00	0.90	4.80	1.00	0.57	**12.27**	**12.50**
2043		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.24	5.41	5.00	0.90	4.80	1.00	0.64	**12.34**	**12.50**
2044		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.30	5.47	5.00	0.90	4.80	1.00	0.72	**12.42**	**12.50**
2045		0.35	1.81	1.39		0.04	0.62	0.49		0.03	0.44	0.39	5.56	5.00	0.90	4.80	1.00	0.80	**12.50**	**12.50**

NP Cost at 3%	162
NP Cost at 6%	122
NP Cost at 9%	101

Capital Cost :	71
Operation + Maintenance	3
Pumping Costs	2
URV (at 6%)	0.74