THE CONSTRUCTION OF DAMS TO ENSURE WATER SECURITY IN SOUTH AFRICA

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THE CONSTRUCTION OF DAMS TO ENSURE WATER SECURITY IN SOUTH AFRICA

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Declaration by student

I, the undersigned, hereby confirm that the attached treatise is my own work and that any sources are adequately acknowledged in the text and listed in the bibliography

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Signature of acceptance and confirmation by student

Abstract

Title of the treatise	:	The construction of dams to ensure water security in South Africa
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Water is vital for all forms of life on earth. Without adequate clean water in a country there will be great suffering and no economical growth.

The construction of dams has always been the primary method to ensure adequate water supply in South Africa. The object of this treatise is to determine whether dam construction is still the best method in ensuring water security. Different areas of concern are investigated such as the financial implication, the environment impact, the positive impact on the economy and alternative methods other than dam construction.

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Chapter 1

The Construction of dams for water security in South Africa

1.1 Introduction

Water is an imperative human need. Without clean, drinkable water there will certainly be a great deal of hardship, sickness and misery. Whether water is a right or a privilege it is important for a country to provide its people with clean water. The social and economical benefits are not debatable.

South Africa is one of the driest countries in the world and with a skew rainfall pattern it makes managing the water resources a difficult task. As the population and the economy grow, the need for fresh water will also increase. The different stakeholders which include government and the private sector need to find innovative means in supplying this growing demand.

In the last hundred years over 45 000 dams have been built around the world according to the World Commission on Dams (2000:1). Dams have been built mainly for the following reasons; to meet the water requirements, to control floods and to generate electricity. On a more regional aspect, dams have had a positive impact regarding job creation, regional development and water supplying for irrigation which leads to food production and even exporting of food, which in all stimulate economic growth.

There are however also a lot of negative impacts surrounding the building of large dams. These include the social impacts for example the displacement of between 40 to 80 million people world wide. The majority of these people do not receive any compensation. The ecosystem impacts include the withdrawal of water for irrigation, the altered river flow and the immediate impact in and around the river.

Large dams are extremely expensive to build. The financial aspect alone gives reason for alternative methods in ensuring fresh water supply.

The aim of this study is to determine whether dam construction is the answer to South Africa's growing water demand or what the alternative methods are.

1.2 Problem statement

Is dam construction the answer to South Africa's growing water demand?

1.3 Sub problems

1.3.1 What is the financial implication of dam construction?

The cost of building dams is substantial and therefore the cost should be well calculated and monitored to ensure that the project will be within budget.

1.3.2 What is the environmental impact of dam construction?

What is the positive and negative impact of dam construction on the environment?

1.3.3 What is the positive contribution of dam construction on the economy?

The impact of the construction of dams on the economy as a whole and the impact it has on the surrounding areas.

1.3.4 What alternatives are there to dam construction?

To ensure water security what alternative techniques can be utilized?

1.4. Hypotheses

Through out the world it is still believed that dam construction is still the best method to ensure water security, even bearing in mind the different negative issues.

1.4.1 With reference to the cost of dam construction that is substantially high. The cost of dam projects can be well managed and the project can be finished within the stipulated time frame.

1.4.2 When looking into the impacts of dam construction on the environment it is clear that there are negative impacts. However there will be positive impacts also and these should be weighed up against each other. In this instance the demand for water should weigh more than the negative impacts of dam construction.

1.4.3 The positive impact of dam construction on the economy will be a massive positive input as well as the development of the mostly rural surrounding communities and these two factors together with water supply should play the biggest role in opting for dam construction.

1.4.4 The alternatives for dam construction is either not feasible for the South African or have not been researched sufficient. Further research is being done and if these alternative resources are feasible for the South African context then it might be used in the future.

1.5 Delimitations

In the research done there have been a number of areas that has not been studied.

Firstly the financing of dam construction projects through government or private financial institutions have not been studied.

Secondly the design of the dam wall and the related issues concerning civil engineering aspects such as material use ext. has not been researched.

Thirdly the construction methods and different techniques applicable to the construction of dams have not been included in the research field.

1.6 Importance of the study

South Africa is a water scarce country and the economic and population growth has put tremendous strain on the available water resources. It is now up to the South African government to ensure that sufficient water can be supplied for all different sectors.

The question is now raised what the most appropriate method would be to ensure water supply. Therefore this study is undertaken to determine whether to construct dams would be the best solution in ensuring water security.

1.7 Research methodology

In order to solve the above mentioned problems, books and journals as well as articles form the internet will be consulted. A well known engineer in the dam construction industry will also be consulted.

Each problem will be studied separately, but the main problem will always be kept in mind.

Chapter 2

The Financial implication of Dam Construction

2.1 Introduction

A dam project will only be approved on a basis of a very strict financial budget. If a dam costs more than what it was budgeted for, additional funds need to be obtained. Dam projects can cost billions of rands and therefore cost overruns will have a great impact on public and private investments. For dam projects to be under estimated in terms of the final cost of the project, it will have a substantial impact on cost recovery. Research done by the World Commission on Dams (2000:1) clearly shows that more than three quarters of dam projects studied had cost overruns. It is therefore very important to identify the key factors that make up the cost for a dam project, the factors that would change the cost of a project and the key areas that can be monitored and controlled to ensure that dam projects stay within budget. These important points should be addressed to ultimately insure that the project would be feasible in terms of supplying water cost affectivity.

Every project is unique no matter how similar they are. Most differences would normally be within the technical category, but economic and regional factors would also play a huge part in the fact that no two projects would be the same.

2.2 Factors that will influence cost

Because no two projects would be the same, it is important to identify the factors that will determine the cost of a project. Hereunder some factors are discussed that make up the cost of a project.

2.2.1 Project Specification

The specifications define the physical characteristic of a project. In a dam project it would define what the capacity of the dam should be, what the amount of water needed from the dam would be, what the provision should be for flood control and for water release through the over flow etc. Normally the more detailed the specifications the more expensive the project. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:9.)

2.2.2 Location

The location of a project would affect the cost through geographical and statutory factors. The initial project cost can be affected negatively by statutory factors such as the extra time to approve the project from a legislative point of view. If a project is located in an environmental sensitive area this approval by government, the local community and environmentalists would be a difficult and long process and this need to be taken into account when estimating the cost of the project. When geographical factors are studied the following would be important to evaluate. The material cost and the cost for land would vary substantially because of the distance from suppliers and local area factors such as the climate and weather conditions. Then factors such as if a project is in an urban area or in a rural area must be taken into account. If a project is in a rural area the cost for material would normally be high because of transport cost and in an urban area the cost for land would be high. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:9.)

2.2.3 The form of contract used

The type of contract used would have an affect on the cost of the project. If a lump sum contract is used then some contract savings can be expected but not substantial. If a contract is used which transfer most of the cost over-run from the employer to the contractor, costs may be saved and better time management from the contractor can be expected. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:9.)

2.2.4 Site Characteristics

Factors such as site restrictions and soil conditions would have an impact on the original cost. Poor ground conditions ultimately would affect the amount of excavation, piling and grouting that would have to be done. Uncertainty about ground conditions can be one of the most important factors to negatively affect the project cost. Therefore in order to determine the soil and rock conditions before the start of the project boreholes must be sunk. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:9.)

2.2.5 Newly build or improvements

It seldom happens that dams are renovated or improved but since the devastating floods of the year 2000 the Department of Water affairs found that the outlets for the majority of the dams in South Africa will be too small for any bigger floods and have therefore instructed that the dam's outlets must be enlarged. Although it is common sense that a new dam would cost much more than just an upgrade of an existing dam, this upgrading can also be very expensive and great care must be taken to ensure that the estimate will be correct and that the cost should be within budget. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:9.)

2.2.6 Tax Liabilities

It is the norm that a company would have to pay taxes on any profit it makes out of a project. There is however exceptions like where some government projects the companies are exempted of paying taxes. This can be an important factor in determining the project cost. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:10.)

2.2.7 Timescale

It normally happens that the longer a project is the higher the cost will be. The timescale of a project will be determined by the specifications. Large projects often take longer to implement. This can however be reduced by increasing resources. There might be projects that will take longer because their phases are not continuous or that the phases are dependent on other factors such as public financing. A project that all the phases are following after each other will normally be cheaper because no additional cost is needed to re-establishing contractors and plant. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:10.)

2.2.8 Inflation

It is well known that the longer the project will take to complete the higher the influence of inflation on the cost of the project will be. Therefore great care should be taken in ensuring that the project will be completed within the specified time. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:10.)

2.3 Factors that will influence the cost during the construction period

In the above section the factors that make up the cost of a project was discussed. It should also be remembered that even though all the cost of a project has been calculated and the estimate as accurate as possible there will be factors that still will have an impact on the cost of the project.

Delays play a huge part in this regard. Because delays will ultimately increase the project period, the additional time will have a negative effect on cost due to a number of reasons. Some of these factors that will change the cost of the project during the construction period will now be discussed.

2.3.1 Poor Project Management

The Project manager or the project management team has the greatest influence on cost control. A project manager will have an effect on all the stages of the project. He must ensure that the planning and coordination must be as effective as possible. If the communication between the project management team, the project sponsors and the contractor is poor then delays and cost over runs will surely be inevitable. Thus it is crucial to appoint a good and experience project manager to ensure that costs will stay with in targeted areas. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:11.)

2.3.2 Design Changes

There can be numerous reasons for design changes like if the sponsors want to add certain elements or change a feature. These changes will have in increase in the time and the effort from all different parties, from the engineers to the contractor. Design changes at a latter stage in the project will also have a greater impact on cost as if it were to happen in the early stages. Design changes should therefore be kept at a minimum and try to change the design as early as possible. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:11.)

2.3.3 Unexpected Ground Conditions

No matter how thorough the ground conditions have been inspected by borehole and trial pits the actual ground conditions will only be found when construction begins. It may have happened that certain ground conditions was overlooked or that subsoil conditions have changed. In some cases these ground conditions differ from the expected so much that new designs are required. This will have a great impact on cost and will increase the project period. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:11.)

2.3.4 Shortages of Material and Plant

It may happen that in a certain areas construction activity is so high that it is difficult to acquire the necessary construction machinery and materials. In 2007 cement was scarce. With not even taken into consideration the inflation on cement but the actual delay in waiting for cement, contractors suffered great delays and increased costs. Therefore the supply of materials and plant should be evaluated carefully in the tendering stage. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:12.)

2.3.5 Exchange Rates

South Africa import substantial amounts of materials and plant from other countries such as China, India and Europe, therefore the impact of the exchange rate on South Africa's construction industry will be substantial. It would be very difficult to determine the exchange rate for the entire project period therefore great care must be taken in the estimate to allow for these changes. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:13.)

2.3.6 Inappropriate Contractors

Contractors are selected on their quality of work record and on the tender price. A contractor must also have the necessary experience in the particular field and have sufficient resource to complete the project on time and at the standard required. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:13.)

2.3.7 Funding Problems

If the estimated cost has been exceeded it may be difficult for the project sponsors to obtain extra fund to complete the project. Sponsors must ensure that they will be able to obtain sufficient extra funds if so required. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:13.)

2.3.8 Land Acquisition Costs

Where the land is not owned by the project sponsor the land need to be purchased. If the owner refuses to sell the government can intervene by statutory legislation. It can happen that the land cost will then be more than what was made provision for. (Understanding and monitoring the cost-determining factors of infrastructure projects, user's guide 1998:13.)

2.3.9 Acts from God

These factors will include earthquakes, fire, extreme weather, political riots and many more. The contractor normally will insure against these factors but still it will affect the cost.

2.4 Cost estimating and contingency

Estimating the cost of construction projects and in this case particularly dam construction projects is very difficult. This is because there are many uncertainties and risks especially in the beginning of the projects where there is not sufficient information available yet. More information will become available as the project progresses. This will allow calculating costs more accurately. Still no matter how detailed information is obtained and cost calculated there will always remain a degree of uncertainty. That is why estimators will add a contingency amount into the estimate. It can be described as an "insurance amount". This contingency amount is normally a percentage of the gross cost that is added to the estimate. The problem with this is that the contingency amount is normally only calculated once and not assessed regularly. Another problem with this method is that different risks are all calculated together and not split individually. Therefore the contingency amounts will rarely reflect the true risk of the project and the cost these risks hold in.

It is therefore crucial to know which factors will have an effect on the cost and which factors are more likely to change the cost of a project. To manage risks will be the greatest tool to ensure that a project will be within budget and in the specified time frame. Risk can be reduced if greater attention is give to identify the risks and managing risks. If a risk is identified it should be monitored and managed throughout the project.

The initial cost of a thorough risk assessment might be higher than what was budgeted for but this will reduce the amount of contingency and a more accurate final project cost.

It is not always known what is contained in the contingency amount. For large construction projects it should cover at least special risks contingency, design and construction contingency. Special risk contingency will cover risks like higher land cost, statutory compliances, and "acts from God." Design contingency will cover for any design changes and construction contingency any site conditions that could influence the cost.

For these more detailed contingency costs to be effective it should be well managed by the project manager. The main areas of project management should be cost, time, quality and change control but these factors will not be go into further in this study.

2.5 Summary

Any dam construction is a very expensive project. Dam construction projects are notorious for having cost and time over runs. These two factors make dam construction a less popular method in providing water for South Africa. But as seen in the above paragraphs the cost can be well calculated. It is possible to estimate the final project cost as accurate as possible if the factors are known that will influence the cost of the project and if greater detail is given to working out the contingency amounts more carefully.

2.6 Test of Hypothesis

What is the financial implication of dam construction?

As indicated in the study the cost of construction of dams will be substantial, however with great care and planning, costs can be managed to insure a financial feasible project and an economically viable infrastructure project. Thus the hypothesis is correct.

Chapter 3

The Impact of dam construction on the Environment

3.1 Introduction

The environment is very fragile. No matter what type of project is undertaken it will have some sort of impact on the environment. It is important to know what the impacts will be and whether it will be positive or negative.

The construction of a dam will most definitely have negative impacts on the environment but some of these can be minimized. It is therefore important to know what the different impacts will be and what can be done to avoid or minimize it.

3.2 The obstacle caused by dams

3.2.1 Floating Debris

The passage for trees, floating debris, fish and ships will be obstructed by the dam. This effect can be solved by providing fish ladders, shipping locks and timber chutes. Overflow spillways will allow debris to pas the dam easily.

3.2.2 Solid Load

Because the dam will obstruct the carrying of solid matter by the river it will have an impact on the environment downstream from the dam. Normally the erosion process will erode solid matter from a certain area and new material from upstream will then be deposited in the place of the material eroded. This new solid matter normally referred to as silt, have great attributes to revive new life. Because the dam obstructs the transportation of silt, some areas can become less fertile and ultimately have a negative effect on the flora of that embankments and flood planes. New dam designs are addressing this issue. Chemical fertilizers can be used although this will be expensive.

3.2.3 Nutrient Transportation

Less nutrients will be carried down the river and will have an effect on the fish species in the river it self and in the estuary. But there may be positive impacts also like in shallow dams where there is an increase in plankton.

3.2.4 Floods

Because one of a dam's functions is to control floods, floods will no longer occur. The committee on damming and the environment (1980:51) indicates some benefits from floods are that:

- "They provide ready access to spanning grounds (ponds and lakes) and renew the water in them,
- They form small islands used by migrating birds to escape from predators on the shore,
- The prevent the river banks to becoming overgrown with trees, and stop mammals destroying the river-side grasses needed to sustain migrating birds, and
- They bring nutrients into lakes and ponds."

These floods can be mitigated by releasing sufficient volumes of water at a proper time and the correct duration.

3.3 Flooding Effect on Fauna

The dam will affect the fauna upstream dramatically. Firstly many animals will die, or migrate, others might adapt to the new environment like amphibian species. The second effect is the animals that migrated or that have been saved now have to be relocated. The area in which they will be relocated to is already in equilibrium and thus this area too will be affected. However the new environment that is created by the dam can have a positive impact on water birds and certain fish species.

3.4 Effect on climate

Whether or not large dams can have an effect on the climate is still a debate that is going on. According to The committee on damming and the environment (1980:55) studies show that the rainfall pattern in Ghana around Lake Volta has changed and the first rain fell at Aswan after the completion of the Nasser Lake.

3.5 Effects on reservoir water

3.5.1 Temperature

Deep dams normally have warmer water near the surface and colder water deeper down. This upper layer is heated by the sun. In warm areas the colder water would be used for industrial, household and power generating purposes.

3.5.2 Oxygen Shortage

Oxygen is needed to sustain all life. Different species of organic material required oxygen to survive and to grow. Fish and other respiratory organisms also depend on oxygen for survival.

“The natural oxygen content is 13mg/l for cold water and 7.5mg/l for warm water. Warm water fish need 4 mg/l to sustain life and reproduce.” (The committee on damming and the environment 1980:57.) Plant material need oxygen to degrade, thus if water is heavily loaded with plant material great amounts of oxygen will be used in this regard, decreasing the oxygen levels drastically. If water with low oxygen content is released from out the dam in great volumes it can have negative impacts on the living organisms down stream from the dam.

3.5.3 Eutrophication

According to The committee on damming and the environment (1980:59) this condition involves the water in a dam and the bottom sediments become enriched with nutrients to such a point that the nutrient levels in the water is dangerous. This will mean that the water can not be used for domestic or industrial purposes. The water will normally have a bad smell.

3.6 Biological effects

3.6.1 Health effects

"Some diseases are transmitted through pathogens whose vectors live in fresh water. Such diseases are endemic even before construction of the dam but the dam increase the size of the hosts' habitat, so promoting their expansion." (The committee on damming and the environment 1980:63.) Diseases spread mainly in this regard as Malaria and Bilharzia are transmitted by mosquitoes and snails respectively.

3.6.2 Fauna and Flora effected

Some unrestrained escalation of aquatic flora can occur in especially tropical areas. This can badly effect navigation, fishing, it can provide breeding places for insects that carry diseases and it can block the water intakes. Examples of this are water hyacinth and lettuce plants. This can however be managed by spraying herbicides on these problem plants.

Dams can have positive effects on aquatic fauna with an increase in the fish population. The fish found is not always the same as in the natural waterways. Fish that migrate there can be made provision to allow for this natural event to still be possible. This can be done by constructing fish ladders which is a series of connected pools that will allow the fish to reach the top water level of the dam in order to swim stream up.

3.7 Action on other water not in the dam

3.7.1 Drying up of rivers

The drying up of rivers or the diversion thereof is not only catastrophic for the environment but also for industries like tourism. This however can be managed by ensuring an adequate release of water from the dam to sustain all living organism dependent on the flow of the river. It can vary from season to season or day by day.

3.7.2 Changes in the water table

Dams can alter the depth of the water table. In some areas where the water table is already near the surface great care must be taken. In other areas the water table can be raised as to the best depth for farming purposes.

3.7.3 Catchment Management

It is normally necessary to take certain actions in the catchment area in order to protect the newly build dam. Deforestation and agricultural development that could lead to erosion should be well controlled. If this is not controlled this could lead to the silting of the dam and good agricultural soil can be lost especially at steep land.

3.8 Land Slides

Dams can cause landslides on the banks, which can partially fill the dam. (The committee on damming and the environment 1980:71) scribes the most striking example in Italy where a land slide occurred. 250 million cubic meters of rock slipped into that only 168 million cubic meter dam. The water was flung over the dam wall which did not break and 3000 people where killed in the valley below the dam.

3.9 Induced Earthquakes

The question whether dams will cause earthquakes has been studied for a number of years. Extensive studies during the filling of the Kariba Dam in Zimbabwe from the year 1959 to 1971 were done. Seismic activity under the Kariba Dam was strikingly parallel to the rise in water level over the five-year filling period and the main earthquake of magnitude 6 occurred when it reached top level for the first time." (The committee on damming and the environment 1980:71.) Although it is therefore evident that the filling of a dam will trigger earthquakes it can not be controlled.

3.10 Summary

The impact of dam construction on the environment is a reality. Some impacts are greater or more negative than the others. There is however ways in minimizing the effect of these impact. To minimizes or avoid these negative impacts an environmental friendly dam must be designed. Since the effects of dams have been studied new design techniques have been developed. It is therefore possible to minimize the impact of dam construction on the environment.

3.11 Test of Hypothesis

What is the environmental impact of dam construction?

The study indicates that there will be positive and negative impacts caused by dam construction. This can however be minimized but not completely. The question whether the negative impacts of dam construction will be so severe that the project should be cancelled, must be evaluated each project individually. The study shows that the impacts can be minimized and therefore the need for water must weigh more than the impacts caused by dam construction. Therefore the hypothesis is correct.

Chapter 4

The Economical Impact of Dam Construction

4.1 Introduction

Water is essential to support all forms of life on earth. It is however not evenly distributed over the world by season or location. Some countries experiences very dry conditions and in others there is such an abundant amount of water that it can create floods and destroy property and loss of life. Dams have been successfully used in history to collect, store and manage water for a sustainable community. The development of cities, industries and agriculture depend heavily on the amount and quality of water recourses available. (International commission on large dams 1999:2)

According to the International commission on large dams (1999:2) "Today there is a significant demand on the world's water. As the world population continues to grow at the rate of over 100 million people each year, so does the demand for water. At the same time, there is a careless use of our natural resources and accelerated pollution of the environment. The fact that a significant portion of the available water in the world is too contaminated for domestic use makes this situation very critical."

The international commission on large dams (1999:2) has stated that one of the best ways to manage water resources is by the construction of large dams for the storage and future distribution and that there are about 45 000 dams higher than 15 meters throughout the world. These dams store about 3600 km³ of water. "The primary benefit of dams and reservoirs in the world is water supply. Other key purposes and benefits include:

· Irrigation for agriculture (food supply)
· Flood control
· Hydropower
· Inland navigation
· Recreation" (International commission on large dams 1999:2)

Usually dams are built for more than one purpose. This creates a wide variety of economic benefits. The employment of local people during the construction of the dam is also another local benefit.

Underneath is a short introduction concerning the different benefits of dams before a more detailed discussion will follow.

The corner stone for any socio-economic development across the globe is the availability of good quality water and in a reliable and adequate quantity. In the past the main resource that has been used to ensure the supply of water for domestic and industrial use has been aquifers. However these aquifers are over used today and the rate of recharge is far less than what is extracted. The water supply from aquifers has to be supported by dams. Large urban areas rely heavily on water from dams, especially in dry areas and in drier cycles with low rainfall. The need for stored water will continue to rise because many aquifers are over-used. The International commission on large dams (1999:3) have found that "the world wide per capita water demand for water would have risen to about 750 litres per day in the year 2000".

If dams are properly planned, designed and constructed it will contribute greatly to our water requirements. "The primary source of fresh water is from precipitation. Throughout the world, the hydrologic cycle varies and is not predictable. Of the total precipitation only one third remains for the runoff to out rivers, the rest is lost to infiltration and evaporation." (International commission on large dams 1999:4.) This is therefore the reason why dams are built. It is because the hydrologic cycle varies so much that dams are required to store water and the provide a consistent yearly supply.

One of the biggest uses of water on a worldwide scale is agricultural irrigation. "This will account for about 1147 litres per day per capita by the year 2000. Since the early 1990s, less that one fifth of the land suitable for agriculture in the world has been irrigated, and it has contributed to about one third of the world food production. It is estimated that 80% of additional food production by the year 2025 will come from irrigated land.” (International commission on large dams 1999:4.) Most of the areas that need irrigation for agricultural development are in arid zones and mostly in developing countries. Even though great technological improvements are being made in the agricultural industry to conserve water, more dams will be required.

Dams are also effectively used to regulate the river levels downstream and controlling floods by temporarily storing the flood volume and releasing it later. The most effective method of controlling floods is done by a number of dams strategically positioned in a river system. This is done by managing the water levels in all of the different dams and planning carefully when and how much water should be released out of a certain dam to minimize the effect of floods. Water control management plans are drawn up to ensure the greatest economical development potential and with substantial involvement from the public.

Energy is needed for socio-economic development of any country. There are many advantages if one can use energy that is clean and renewable. Hydropower meets these requirements. The most technically advanced and economical source of renewable energy at the moment is hydropower. “Less than 20% of the world’s estimated feasible hydropower potential has been developed. The greatest amount of potential remains to be developed in Asia, South America and Africa.” (International commission on large dams 1999:5.) Hydropower projects generate energy very effectively and with limited pollution or waste. Hydropower projects can be developed on a small scale for local use or very large as part of the national system. As part of a multipurpose project, hydropower can also help to finance other functions such as irrigation water, flood control or drinking water.

The biggest problem for inland navigation is the changes in river levels. There are many advantages of inland navigation over highway and rail which is mostly the large load carrying capacity of each barge and therefore the savings in cost such as fuel. If dam projects are planned and designed carefully, inland navigation can become a reality and great economical benefits will be the result.

Dams also have positive impact in its attractiveness and the development of tourism. This is even more important in areas where natural surface water is scarce or non-existing.

4.2 Irrigation Dams

According to the World commission on dams (2000:42) irrigation projects are made up by the dam as source of water, the irrigation system that consist of canals and irrigation technology on the farms, agricultural systems which include crop production and the wider rural socio-economic system and agricultural markets.

To evaluate large dam irrigation projects one can look at the following factors:

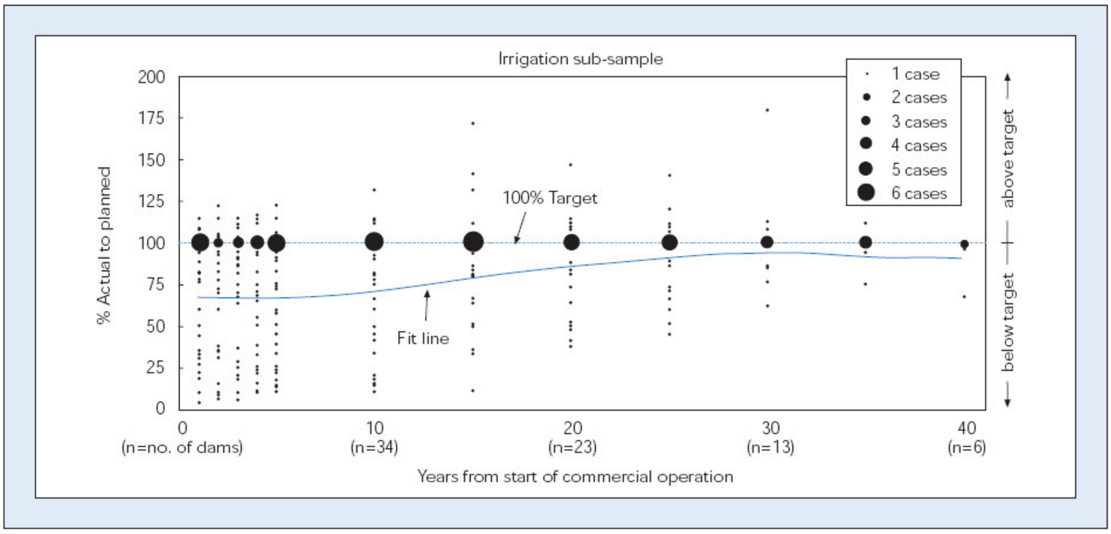
- "Physical performance on water delivery, area irrigated and cropping intensity;
- Cropping patterns and yield, as well as value of production; and
- Net financial and economic benefits." (World commission on dams 2000:42)

Studies done by the World commission on dams (2000:42) have found that irrigation dams have typically fallen short of its physical targets and have failed to recover the costs. Therefore it was less profitable than what was expected initially.

4.2.1 Irrigated area and cropping intensity

The actual irrigated area compared to the planned targets over time has been studied by the World commission on dams (2000:42) and a figure has been drawn up by the information. In figure 1 it is clear that during a project life cycle performance is very poor during the early stages. The actual irrigated area compared to what was planned for each period increases from about 70% in year five to almost 100% by year 30. Like the underperformance in terms of area irrigated the trend continues with respect to cropping intensity. The under achievement by cropping intensity is less that the area irrigated compared to what was planned. The World commission on dams (2000:43) has also found that with regard to the intensity of crop production there is not much of a difference between single and multi-purpose dams.

Figure 1 Actual irrigated area compared to planned targets over time. (World commission on dams, 2000:43)



The study also revealed that smaller dams tend to achieve the targets for area irrigated and crop production easier that larger dams. In this regard larger dams can be seen as dams with area greater that 10km² or dam walls higher than 30 meters.

"The under-achievements of targets for irrigated area development from large dams have a number of causes. Institutional failures have often been the primary causes, including inadequate distribution channels, over-centralised systems of canals development. Technical causes include delays in construction, inadequate surveys and hydrological assumptions, inadequate attention to drainage, and over-optimistic projections of cropping patterns, yields and irrigation efficiencies, including the late realisation that some areas were not economically viable." (World commission on dams 2000:45.)

4.2.2 Cropping patterns, yields, agricultural production.

According to the World commission on dams (2000:46), crop yield and the gross value of production from large dams have often varied significantly from those predicted at the outset of the project. Lower yield are mostly seen for food grain production which was selected in the planning documents but farmers tend to choose more profitable crops and are not always the crops specified in the planning documents. "This will lead to higher than expected gross value of production per unit of area with the caution that such increase have varied with long-term real price trend of the relevant agricultural commodities. But when changes in cropping patterns are combined with shortfalls in area developed and cropping intensity, the end result is often a shortfall in agricultural production from the scheme as a whole. Gross value of production is higher where the shift to higher value crops offsets the shortfall in area or intensity targets." (World commission on dams 2000:45.)

The World commission on dams (2000:46) have found that lower than expected yields have been caused by agronomic factors. These factors include cultivation practices, poor seed quality and pest control, unfavourable weather conditions and the lack of labour and sufficient financial resources. The physical factors that caused lower yield where poor soil drainage, unsuitable land, inefficient and unreliable irrigation systems and salinity. The efficiency of the irrigation application not only effects the production of crops but also the demand on water from the dam.

"In 1990 World Bank study on irrigation mentions that of the 192 irrigation projects approved between 1961 and 1984 only 67% performed satisfactory against their targets." (World commission on dams 2000:46.)

4.2.3 Financial and economic profitability

"Since the 1930s in the industrial countries and from the 1970s in developing countries, financial and economic profitability have become an important, if not the dominant decision criteria in water projects." (World commission on dams 2000:46). Thus for the approval of many large dam projects the profitability of the project in terms of financial and economical value is very important. The financial profitability will indicate to the owner if the project will be profitable. Economically profitable will indicate to society if the project will improve the economy of the whole nation. It is therefore important to highlight the fact that even though some projects might not be profitable in the financial sense of the word but will enhance the welfare of the community and the region and the whole country for that matter.

4.2.4 Cost recovery

Many public infrastructure projects have not attempted to recover costs. "Where the services provided by the large dams are valued as consumption goods or productive inputs, the absence of cost recovery by the sponsoring agency is often equivalent to a subsidy in the sense that large dam projects provides a benefit for which no fees are paid." (World commission on dams 2000:48.)

The study done by the World commission on dams (2000:47) on the cost recovery of operational and maintenance cost indicate that irrigation systems worldwide show a considerable variation of recovery. In public projects it is around 30-50% and private projects that are managed locally total cost recovery for operating and maintenance cost is possible.

"The tendency to poor financial and economic performance and the failure to recover operational and maintenance cost suggest that even where it is an explicit objective, recovery of capital costs will be limited." (World commission on dams 2000:49.)

To sum up the assessment of large dam irrigation projects it can be said that even though there is a considerable variation in performance throughout the world, these schemes have too often fallen short of targets set and have failed to recover costs. There is also too many case that the economical justification for the approval of the project could not be supported by sound information collected to indicate this justification.

4.3 Hydropower Dams

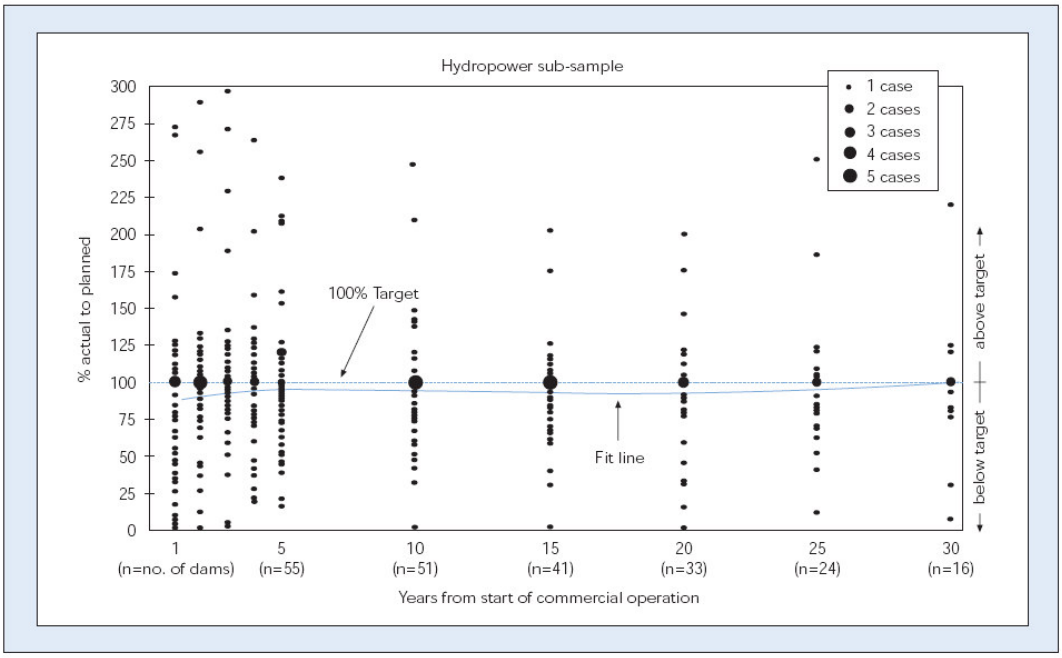
Studies done by the World commission on dams have shown three distinct groups of dams. The first group of dams is those that have performed much better than what was estimated, the second group, is the dams that have fallen extremely short of their targets. The third group is the dams that have performed well and have generated power within a close rage of the targets set but mostly just fell short of it. The last group mentioned were the bulk of the projects. As with other large dam projects, hydropower dams have also incurred schedule delays and cost overruns. "Limited available evidence suggests that hydropower projects often diverge substantially from their economic targets, in either a positive or a negative direction. Financial performance is more consistent and with less downside variability." (World commission on dams 2000:50). There is however some very old projects that still continue to generate power after more that 50 years of operation.

4.3.1 Delivery of services and benefits

Dam projects studied by the World commission on dams (2000:50) typically show that the projects have on average met the expectations for the delivery of power but considerable variability. In reference with the technical, financial and economical targets a number of projects have excelled but there have been also those that have fallen short. In order to examine the delivery of services a benefits one must look at the targets for installed capacity and delivery of power. Hydropower offers supplementary services to the electricity supply network.

As indicated in the next two figures attained from the World commission on dams (2000), hydropower projects performance was on average much closer to the targets than what was the case for irrigation dam projects (see figure 3). But as in the case for irrigation dams the variance in performance was large (see figure 2). "On average, almost half of the sample exceeded the set targets for power generation – with about 15% exceeding targets by a significant amount. It also shows that around one-fifth of the projects in the sample achieve less that 75% of the planned targets." (World commission on dams 2000:50). Figure 3 shows that more that half of the projects in the sample fall short of their power production targets. A couple of over performers maintain desirable average. This however should not hide that fact that there are a considerable amount of projects that fall short of their targets in power delivery.

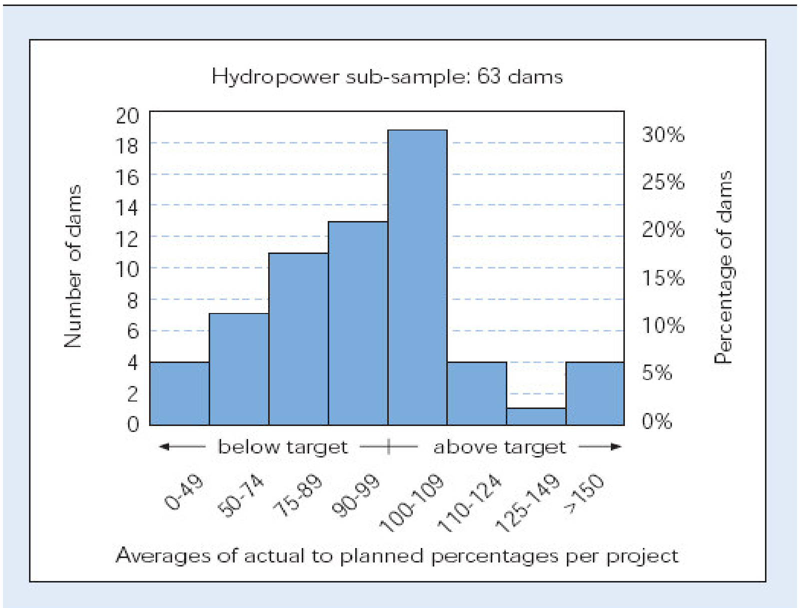
Figure 2 Actual versus planned hydropower generation over time. (World commission on dams 2000:51).



These so called over achievers in power output, is mostly due to the fact that additional generating capacity has been installed prior to commissioning and even more installed after commissioning. “One-quarter of the large dams with higher-that-expected output had installed more than 100% of the capacity planned in the feasibility study.” (World commission on dams 2000:50.)

Figure 4 shows that the installation of more than originally expected capacity will lead to higher-than-expected power output. “The Tucurui dam diverged from feasibility design when initial installed capacity was raised from 2700 to 4000 MW before commissioning. Tarbela, Grand Coulee and the Glomma and Laagen dams have all seen subsequent installation of significant amounts of additional capacity that were not foreseen at feasibility.” (World commission on dams 2000:50.)

Figure 3 Project averages for actual versus planned hydropower generation. (World commission on dams 2000:50.)



There is however also instances where the energy output is lower that what was initially estimated.   “The Victoria dam in Sri Lanka had a predicted energy generation of 970 GWh/annum, but in reality only produced an average of 670

GWh, a shortfall of over 30%. Higher-than-expected upstream irrigation abstractions and lower-than-predicted natural stream flows were the causes in this case." (World commission on dams 2000:51). In the case study done by the World commission on dams (2000:51) the Pak Mun project, which is a run-of-river project, showed that in the project's first four years of operation the installed capacity and the total energy generation were as expected. But the project fell short of its initial planned delivery of providing energy for a four-hour peak period, leading to the subject whether the project can be regarded as economical viable.

Figure 4 Capacity and power generation. (World commission on dams 2000:52.)

Further shown in figure 2 is that the average generation in the first year of commercial operation is 80% of the targeted value for large hydroelectric dams. Thereafter between year two and year five it nearly rose to 100% of the targets, however this improvement in the average is mostly due to a few dams that perform very well and as stated earlier there are still a great number of dams that fall far short of the targets. “Delays in the construction phase of projects, in reservoir filling, and in installing and bringing turbines on-line explain shortfalls in performance in the early years of commercial operation.” (World commission on dams 2000:52). Delays in the installation capacity happened at Kariba and a subsequent delay occurred in the generating targets especially in the early years.

Another reason why targets are not met in the early years is unexpected events and design changes during the project development stage. At the Tarbela project there were major structural damage during the commissioning trails and it led to a two-year loss of power generation. At the Van der Kloof dam delays occurred because a decision was made to increase the generating capacity and that meant that the dam wall had to be increased in height. If delays are not because of a slower that expected demand for electricity, these delays can have a serious negative effect in providing power to consumers and economical benefits.

A very important factor also studied by the World commission on dams (2000:52) is the consistency in generating over time. Some large dams have increased its generating output over long periods. An example of this can be seen in figure 4. Grand Coulee power production has trended upward for the last 60 years, but it is over shadowed by significant inter-annual variability.

The variation on power production over time has also been studied by the world commission on dams. Normal variations in weather and river flows dictate that virtually all hydroelectric projects will have year-to-year fluctuation in output. The effect of drought years can be easily seen in the large swing in annual power generation from Grand Coulee and Kariba, particularly over the last two decades.

Whether changes in regional and global climate are exacerbating normal weather-related inter annual variation remains to be seen. Such variation may also reflect changes in other demand and supply factors." (World commission on dams 2000:53.)

4.3.2 Technical efficiency and ancillary

Case studies such as the Glomma and Laagen and Grand Coulee case studies done by the world commission on dams indicate the improvements in generation were achieved by several factors. These factors include the adding of new powerhouses to the same reservoir, the upgrading of existing turbines and generation equipment, adding additional turbines or the optimising of the reservoir operations to improve performance.

"These experiences of improving the performance of hydropower generation over a project's life are not confined to industrial countries. In Nepal, modifications to the intake, provision of an extra desander, dredging the forebay and refurbishing the generators/turbines and power house control systems at the Trushuli-Devigahat hydropower station in 1995 improved average annual power generation by 46% - from 194 to 284 GWh a year." (World commission on dams 2000:53). In North America and Europe the industries are optimising reservoir operations and power dispatch schedule by making use of more sophisticated 'decision-support' systems.

This decision-support systems guide the weekly reservoir release decisions. This system will enhance the efficiency of power generations.

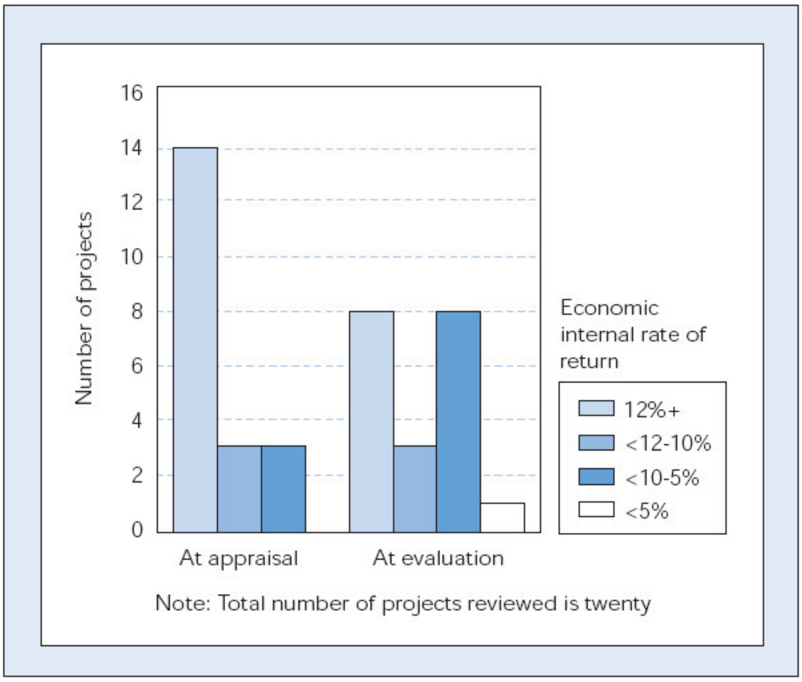
4.3.3 Financial profitability

There is a wide variation in the economic performance for hydropower projects due to schedule delays, cost overruns and variability in power delivery. Data from the World commission on dams (2000:54) shows that the operating and maintenance cost of hydropower projects rise over time.

Large hydropower dams studied by the world commission on dams confirm that there is a large variability in meeting economic targets and achieving financial profitability. However it is unlike irrigation projects, hydropower projects are not only to the negative but there are a couple of projects that perform far better economically that what was expected. "Much less variation is observed in financial performance relative to targets, although there is a wide spread in terms of actual financial rates of returns." (World commission on dams 2000:54.)

Evidence compiled by the World commission on dams (2000:54) from multilateral bank appraisals and evaluation studies shows that although a number of hydropower projects fall short of their financial and economic targets and can be considered economically unprofitable, others meet their targets or even exceed expected profitability (see figure 5). Of 20 World Bank projects reviewed, 11 fell below initial targets and seven rose above these targets; overall, nine projects had returns below 10% but only six of the projects actually fell to his level (the other three already had low rates of return at appraisal). These evaluation studies do not reflect long-term performance data, but rather the effect of cost overruns and initial lags in performance." (World commission on dams 2000:54.)

Figure 5 Multilateral bank evaluation results on the economic performance of hydropower dams. (World commission on dams 2000:54.)



There are only a number of formal and comprehensive financial and economic evaluations available to compare and study the profitability and economic viability of hydroelectric dam projects. Evaluations done by the African development Bank indicate that only four out of the six dam projects evaluated was found economical.

The World commission on dams (2000:56) found that a considerable number of hydropower projects fall short of their initial economic targets, although only a small number of projects can be seen as economically unprofitable if the economy as a whole is also taken into consideration. There are as mentioned earlier as many projects that outperform their economic targets. "Finally, it is worth emphasising that cost recovery has not been a substantial problem for hydropower projects; indeed, the focus is more on profitability in the current context of trends towards private-sector participation in electric power production." (World commission on dams 2000:54.)

4.4 Flood Control dams

Throughout the ages societies have tried to control or minimize the effects of floods by building levees or embankments along rivers. Societies did this in order to occupy floodplains for a number of uses such as agricultural and industrial land needed or to minimize the loss of lives or property caused by floods. The world commission on dams (2000:56) have found that although some dams have provided flood control benefits other dams have increased the threats to some communities.

4.4.1 Flood control benefits

Large dams are used in flood control systems to store water from floods in the dam and then releasing the water over time slowly to minimize the flooding effect. By storing a portion of this flood water it will decrease the peak of the flood. This will ultimately lead to minimizing the peaks from floods in different rivers arriving at the same time in the main-stream of the river. Therefore the main benefit will be to reducing the peak of the flood; this will ultimately reduce the damages to embankments or levees. "Indicators of the benefits derived from flood control include reductions in the area flooded and prevention of any consequent loss of life, social disruption, health impacts and property and economic losses". (World commission on dams, 2000:56.)

4.4.2 Limitations of flood control operations

There are a couple of negative factors that need to be taken into consideration also. This obviously include if the failures of dams. This could lead to devastating effects to communities living down stream from the dams. Another factor is when reservoirs are not operated properly in times of emergency or if the floodgates have mechanical failures during critical times. It is also important to state that this flood control system need to have very well warning systems to the communities below. There has been a number of events that insufficient communication to the communities below the dam has caused human and property loss in flood circumstances.

Areas of concerned identified by the World commission on dams (2000:57) regarding dams built for flood control are the following:

- These dams have encourage people to settle in areas that are still subjected to floods
- The cost to ensure protection against all floods are simply to high
- The effectiveness for flood control by dams will reduce over time because of sedimentation in the reservoir and river beds
- The negative effect on the environment and agriculture caused by the reduction or elimination of floods.

Although it is an expensive exercise, flood controlling does have many benefits. It is however important to keep these negatives in mind when designing and doing the feasibility of flood control dams.

4.5 Summary

The most important positive contribution of the construction of dams is the provision of water. No economy can grow without the adequate supply of quality water. Water is not only used in our everyday lives for drinking and cooking, but more so in the industrial world. Water is an essential part of every factory. Supplying water to South Africa for all the different sectors, from house holds and agriculture to factories and the generation of electricity at coal driven power stations, is the primary benefit of dam construction. The secondary benefits will be the generating of electricity through hydropower projects and flood control.

4.6 Test of Hypothesis

What are the positive contributions of dam construction on the economy?

As mentioned earlier the main benefit of dam construction would be to provide water which is essential for all forms of life and economic growth. There are secondary benefits such as the generation of electricity which could help to make the project more financially viable. Thus the hypothesis is correct.

Chapter 5

Alternative water resources

5.1 Introduction

Comparing dam construction to alternative water resources is an important part in deciding which project will ultimately benefit South Africa the most. Alternative resources have been used in a variety of countries around the world, but the question is still whether these alternative resources are feasible in South Africa. The financial, environmental and economical impacts should be taken in consideration when comparing these strategies.

5.2 Desalination

South Africa has a growing demand for fresh water and the necessity for alternative water resources is of utmost importance. As a country with little to medium rainfall, South Africa requires water to be dammed and piped long distances to reach growing areas. With dams currently used almost to capacity, South Africa needs alternative methods to supply water.

In an article by Tyrer (2005:1) it is stated that the advantage of using desalination is that it alleviates much of the need to draw on groundwater. It also states that the Western Cape wants to use desalination as an option for solving the city's water shortage and investigations are under way for the construction of a desalination demonstration plant on Robben Island. "Desalination may be cheaper than alternative means of bringing water to areas that have little water," says Offringa in Tyrer (2005:1). The WRC has funded a research project leading to the construction of two solar-powered low-energy desalination systems for rural communities in the Karoo.

In South Africa there are two robust units which make use of normal distillation methods and were produced locally based on international technology. The one plant was donated to a rural community, while the other was bought by the Department of Water Affairs and Forestry. Former Water Affairs and Forestry director-general Mike Muller was quoted by Tyrer (2005:2), that desalination is an internationally practiced process. Middle Eastern countries are making extensive use of the technology. The Aden Sea water desalination plant was built by the British government while ruling Yemen to produce fresh water for the community (Al-Buraihi, 2006:1). Australia too is looking into the process following the severe droughts the country has experienced. Representatives of Water Affairs have been involved in tsunami- relief efforts in the Maldives, where desalination plants have been installed to treat the groundwater which has become saturated with salt water after the tsunami. Desalinated water can be used for industrial and domestic or urban sectors, says Muller. The industry will benefit the most from this alternative source, as the supply of water to agriculture can be maintained and it alleviates the problem of farmers competing with cities for limited water resources. (Tyrer, 2005:2)

5.2.1 Method

Fresh water can be derived from seawater by a number of ways. Seawater can be distilled using distillers that can provide us with fresh and pure water. Household distillers are designed for providing water for drinking and cooking. It is not economical to use it for other uses like flushing toilets, bathing, washing clothes, and cleaning. Distillers use heat to boil water into steam which is condensed back into water and collected in a purer form. When the water boils, it leaves impurities behind in the boiling chamber. The rising steam passes into a cooling section and condenses back into a liquid. The condensed liquid then flows into a storage container. Distillers are commonly made of stainless steel, aluminum, and plastic materials. These materials do not absorb impurities from water and are easy to clean. Salty water also can be purified through distillation, and can be used for drinking and cooking. (Tyrer, 2005:2 and Al-Buraihi, 2006:1)

Filtration systems on the other hand can also serve as an alternative approach. This system has been considered to be difficult and expensive in the past, but the development of reverse osmosis and filtration membranes has improved the process dramatically. Reverse osmosis is at this stage the most economical way to desalinate water. The process is however energy-intensive, because it relies on high-pressure methods to move the purified water through the membranes, while retaining the brine, or contaminant-carrying concentrate.

Reverse-osmosis technology is most frequently applied when a cheap source of energy is available. Reverse osmosis can filter water to any degree of purity by passing water repeatedly through the system. Reverse osmosis has recently gained popularity due to the marked improvements in the technology, particularly related to lower energy consumption and environmental impact improvements. (Tyrer, 2005:2)

5.2.2 Economical impact

The disadvantage of desalination lies in its high costs but, with costs decreasing rapidly, it will become a popular option for coastal towns looking for alternative water supplies. Desalination will enable coastal cities and industries to develop faster and more effective. The costs of desalination have decreased substantially in the last ten years. A large-scale plant would be able to produce desalinated sea water for R3,70/m3 rather than the R14/m3 it would have cost a few years ago. The main expense in the desalination process is energy consumption, for it uses approximately 3 kW/h for every cubic metre of water produced. (Tyrer, 2005:1)

The article by Tyrer (2005:2) also highlights the concern that unpredictable and expensive energy costs can have a negative effect on the desalination process. One solution to decrease the costs associated with desalination would be renewable energy sources. The possibility could be hydroelectricity from the

Congo, which is the largest source of renewable energy for Africa. The project is a major resource that could produce 30 000 MW. If this energy could be delivered to the Western Cape cheaply enough, it would provide a source of energy and produce large quantities of water for South Africa.

Another idea is to design a cycle of energy generation at power stations that combines the production of waste heat from the burning of fossil fuels with desalination plants. This may be a viable option, considering the development of new power stations, including the pebble-bed reactor, gas-fire and peaking generators. Muller was quoted by Tyrer (2005:2) that water production requires a power plant that is active 24 hours a day. The process requires baseline power stations rather than peaking-power stations, which form part of the proposals for 2008. These plants would allow for distillation-type processes rather than reverse osmosis. In the desalination process there are two major concerns. The one is still high energy consumption, but the waste products that will form also create a problem. The desalination process produces usable water, leaving an effluent with a high salt content.

5.2.3 Environmental impact

The location of the plant determines the environmental impact it will have on its surroundings. Close proximity to the ocean implies that the brine can be pumped back into the sea with little environmental impact. If the plant is located inland, disposal of the brine becomes complicated and could cause pollution of the groundwater or, if pumped into the sea, could fail to disperse sufficiently. South Africa doesn't really have this problem, as we have deep oceans with good water circulation off our coasts. (Tyrer, 2005:3)

Inland towns would require inexpensive evaporation ponds or, in high-rainfall regions, extra equipment for an evaporation plant. The concentrate may also contain large amounts of chemicals. Conventional desalination systems rely heavily on chemical dosing to reduce the fouling of membranes. Concentrated in the brine reject of the desalination plant, the chemicals constitute between 35% and 65% of the total water balance of the process. Disposal of the chemical-laden brine requires careful planning. (Tyrer, 2005:2)

Membrane technology South African company Graham-Tek Systems is playing an important role in the desalination industry. The company has installed several reverse-osmosis plants throughout the country for the treatment of industrial waste, brackish water and seawater. They also built the largest seawater desalination plant in South Africa, which operates on the Albany coast, near Port Elizabeth, producing 1 200 m3 of potable water a day. GrahamTek has also overcome the problem of chemical-laden brine by developing improved membranes and other innovations that include chemical-free solutions. Its 16-inch membrane systems, mechanical flow distributors and electromagnetic field devices assist in inhibiting the fouling of membranes and reduce energy consumption. The main challenge associated with desalination is that the source water must be pre-filtered correctly to avoid fouling of the reverse- osmosis membranes. Bezuidenhout adds that GrahamTek has developed particularly robust pre-filtration and micro filtration systems for this purpose. Bezuidenhout says "South Africa has become a significant stakeholder in the development of energy-saving and cost-effective desalination systems". (Tyrer, 2005:3)

5.2.4 Feasibility

In the document written by Tyrer (2005:3), Offringa (2005:3) is enthusiastic about desalination and says that the combination of the improvements in membrane technology, the reduction in energy costs and net energy being mostly recovered from the process make desalination the water-treatment process of the future. Muller says that the Department of Water Affairs and Forestry is faced with a number of future challenges. "The increase in people and their improved living standards are increasing the demand for water and this could have a significant impact on the country's water." He stresses the importance of managing water systems and encouraging people to protect water so as to prevent it from becoming a constraint to social and economic growth. (Tyrer, 2005:3)

5.3 Artificial Recharge Schemes

Well construction and pumping methods have resulted in the large scale exploitation of groundwater in India and elsewhere. Replenishment of groundwater by artificial recharge of aquifers in the arid and semi-arid regions of India is of great importance as the intensity of normal rainfalls is inadequate. This statement can also be applied to South Africa as parts are also arid and semi-arid land and the need for fresh water increases each day. (National Drinking Water Mission and Department of Rural Development 1989.)

Techniques such as *nalah* bunding, constructing percolation tanks, trenching along slopes and around hills have been used over the ages, but lacked a scientific basis for selecting the sites on which the recharge structures are located. For this reason the Central Ground Water Board (CGWB) implemented a full-scale technical feasibility and economic viability study of various artificial recharge methods in the semi-arid and drought affected areas of India (1980-1895). The CGWB identified techniques commonly used for artificial recharge, while injection or connector wells are largely experimental others, such as surface spreading methods, are actively used. (National Drinking Water Mission and Department of Rural Development 1989.)

5.3.1 Method

Several methods are commonly used. Channel spreading involves changing the pattern of the surface flow in the river channel using "L"-shaped levees (sand bunds), slowing the rate of river flow and increasing the channel length to provide more time for infiltration. Another type is spreading channels which use artificial, unlined canals to recharge the groundwater reservoirs. These methods make the structures relatively stable and limit the deposition of wind blown silt on the sides of the canals. A variant of this technique is the use of contour trenching. This technique is used more in hilly areas where surface runoff rates are very high. A further variation of the surface spreading technique is the use of recharge ponds, percolation tanks, check dams, and subsurface dikes. These are the cheapest methods of artificial recharge. (Al-Buraihi, 2006 and National Drinking Water Mission and Department of Rural Development 1989.)

5.3.2 Economical Impact

The recharge schemes and related land development activities depend on the cooperation of the community and therefore should be managed at the local level. Many basin development projects, being multi-disciplinary schemes, involve the state irrigation, forestry departments and the local cultivators. Costs of recharge schemes depend upon the degree of treatment of the source water, the distance over which source water must be transported, and stability of recharge structure and resistance to siltation and/or clogging. Table 1 summarizes the costs of various artificial recharge methods. (National Drinking Water Mission and Department of Rural Development 1989.)

TABLE 1. Economics of Various Artificial Recharge Methods

(National Drinking Water Mission and Department of Rural Development 1989.)

Artificial Recharge Structure Type	Capital Cost/1 000 m3 of Recharge Structure	Operational Cost/1 000 m3/year
Injection well (Alluvial area)	$55 1	$21
Injection well(Hard rock)	$2	$5
Spreading channel (Alluvial area)	$8	$20
Recharge pit (Alluvial area)	$515	$2
Recharge pond or percolation pond (Alluvial area)	$1	$1
Percolation tank (Hard rock area)	$5	$1
Vasant Bandhava of Check dam	$1	$1
Tidal regulator	$56	$15

5.3.3 Environmental Impact

Recharge structure depend upon the design to ensure the correct sizing of the pond, to provide sufficient recharge, to meet abstraction demands and to adequately contain storm water runoff. In India, the subsurface dike is the most suitable structure for promoting groundwater recharge as it is safe from floods, needs no elaborate overflow devices and is least susceptible to silting. Two subsurface dikes of 100 m length each, within 300 m upstream and downstream of the water supply well, can capture and infiltrate enough water to service the fresh water requirements of a village of up to 500 people. Check dams are the least favourable form of this technology, and should only be used where the recharge requirement is very high or there is a need to control soil erosion.

In very dry areas, infiltration of rain water is best done by using integrated series of techniques, which, for example, include damming the gullies of minor streams, constructing subsurface dikes and/or percolation tanks along their tributaries, contour bunding and trenching on slopes, placing farm ponds in the foot hills, and, wherever possible, installing check dams on the main stream courses. Terracing of hillsides, which help to retain runoff and increase infiltration, also forms part of an integrated basin-scale water resources development plan.

Artificial recharge structures have to be monitored for their stability during high flow storms during years of above average rainfall and occasional flash floods. In the table below, the suitability of each type of artificial recharge structure is stated. (National Drinking Water Mission and Department of Rural Development 1989.)

TABLE 2. Suitability of Artificial Recharge Structure for Common Water Resource Development Purposes.

(National Drinking Water Mission and Department of Rural Development 1989.)

Lithology	Topography	Type of Structure
Alluvial or hard rock	Plain area or gently undulating area	Spreading pond, subsurface to 40 m depth undulating area dike, minor irrigation tank, check dam, percolation tank, or unlined canal system
Hard rock down to 40 m depth	Valley slopes	Contour bunding or trenching
Hard rock	Plateau Regions	Recharge ponds
Alluvial or Hard rock with confined aquifer to 40 m depth	Plain area or gently	Injection well or connection well
Alluvial or Hard rock with	Floodplain deposits	Injection well or connection well

confined aquifer to 40 m depth		
Hard rock	Foot hill zones	Farm ponds or recharge trenches
Hard rock or alluvium	Forested areas	Subsurface dikes

5.3.4 Feasibility

The various techniques used proved to be effective in storing water for human use in all of the states of India, with the possible exception of the coastal area, where the extreme porosity of the aquifer and its connection to the sea resulted in less water being available than was injected. In the study it has been proved that the recharge systems were effective in minimizing water loss due to evaporation compared with similar surface storage systems. Studies that were carried out in India showed statistical significance and can therefore also be applied in South Africa.

Among the spreading methods, subsurface dikes are most effective as they are lower maintenance, are safe from natural disasters, minimize evaporative losses and avoid many of the environmental problems arising from surface storage. There is also no loss of agricultural lands or forests by inundation as would occur behind a surface storage structure. In cases where channels are used for groundwater recharge, multiple benefits may be achieved by combining irrigation and infiltration channels in a number of river basins.

One of the main disadvantages of recharge structures, such as ponds, trenches, and percolation tanks, is that they require regular maintenance to avoid siltation and clogging of the recharge basin. There is also the possibility of water logging in some areas due to increased groundwater levels. Further, injection and connector wells are costly schemes requiring high order of quality control of the infiltration source water. This method requires knowledge of the geological conditions as well as the rock formations with moderate permeability. Low permeabilities limit storage volumes and high permeabilities do not allow adequate retention of the recharged water. The cost of recharged water also limits its application to ezpand domestic water supplies as it is not economically viable for irrigation purposes in India. (National Drinking Water Mission and Department of Rural Development 1989.)

5.4 Summary

Both these methods can contribute to the cause but only desalination would really make a difference. However it will only be economical at coastal areas and a lot must still be done in the development of the process and in trying to minimize the cost of electricity.

5.5 Test of Hypothesis

What alternatives are there to dam construction and what alternative techniques can be utilized?

As seen in the section above there are some alternatives techniques that can be utilized. Desalination can be utilized in South Africa especially in the coastal provinces and more specific costal metropolitans such as Cape Town, Port Elizabeth, East London, Durban and Richards's bay.

However the two constraints or negative impact that desalination has must be addressed and carefully planned for if desalination would be a method used in these areas. Firstly the cost of energy has to be taken into account. Escom's tariff increase of more that 30% in 2009 will definitely have a huge impact of the feasibility of desalination because of the fact that desalination's main expense is energy cost. But huge strides are being made in terms of energy efficient plants and if renewable energy can be utilised for desalination then it becomes a very attractive alternative water source.

As for Artificial Recharge Schemes it seems that it would be a very complex method of recharging the aquifers that are being over used. Although South Africa are using water from aquifers extensively, if these aquifers are to be recharges with these methods explained above it seems that these methods and dams will be competing over the same run off water from precipitation. Furthermore it was stated earlier that South Africa do not have a high rainfall therefore if water are "stolen" from dams to recharge aquifers then existing dams stand the chance to becoming empty. It would not be a wise option putting further strain on run off filling dams.

Therefore an alternative for dam construction in securing water resources for the socio and economical development, desalination would be a feasible alternative but only for coastal areas. Artificial recharge of aquifers would not be an alternative and therefore inland water resource should still consider dams being the best solution in this regard. Thus the hypothesis is correct.

Chapter 6

Summary

6.1 Background

If looked at the earth from space it appears blue. This blue planet gets its name from the color of water. Even though more that 70% of the earth's crust is made up of water there are some areas that are so dry that it can not support life.

South Africa is one of the driest countries in the world if looked at the rainfall. What makes this worse is that the rainfall pattern is very skew in the sense that it is not evenly distributed by season or location. Even though that in some areas there are not sufficient water to support life, in other areas there is such an abundant amount of water that it can great floods. The question now arise is how to manage South Africa's limited water resources and is the construction of dams the best solution.

As stated earlier more that 45 000 dams have been built over the last hundred years. All over the world these dams have been built for a number of reasons, mainly for the supply of water but also to control floods and to generate electricity.

So far it sounded like a simple solution to South Africa's water demand. However there are negative impacts that need to be looked at to make an objective and calculated decision. Some of these negative aspects are environmental impacts, social impacts and that fact that the construction of dams is extremely expensive.

6.2 Summary

In order to solve this problem different aspects of the construction of dams have been examined. The different aspects studied are firstly the financial impact because of the cost of the project. Secondly what the environmental impact of the construction of dams would be. Thirdly, the positive contribution that dam construction would have on the economy and finally what alternates are there that can be utilised other that dam construction.

Every infrastructure project need to be financially viable. Dam construction projects are no different than that. Infrastructure projects such as the construction of dams are very expensive and will only be financed by large financing institutions such as the World Bank or by government. Therefore dam construction projects will only be approved on a very strict financial budget. It is crucial that the estimate of the total cost of the dam would be correct to ensure that the project will not exceed its budget. Dam projects can easily cost a couple of billion rands and it is therefore important that cost overruns should be avoided at all cost because with cost overruns it would make cost recovery extremely difficult.

To avoid cost overruns one must take great care in estimating the total cost of the project. It is therefore very important to identify the key factors that make up the cost for a dam project, the factors that would change the cost of a project and the key areas that can be monitored and controlled to ensure that dam projects stay within budget.

Some of these factors that would influence the cost of the project are project specification, location, the form of contract used, the site characteristics, tax liabilities, the timescale and inflation. These factors should be taken into consideration when pricing for the project and effort should be made to make the assumptions as realistic as possible. If these factors are used carefully it would ensure a more accurate estimate of the cost of the project and this could ultimately lead to less cost overruns.

Factors that also would have an impact on the price but can be managed or made provision for would be the following. Design changes, unexpected ground conditions, shortages of material and plant, exchange rates, inappropriate contractors, funding problems, land acquisitions and acts from God. Although these factors seem unusual or not applicable it can occur and if they can occur there must be budgeted for it or made provision for it in the form of insurances. It is ultimately important to take note of these factors. A further and the most important factor is the project management of the entire project. The project management team will influence the project outcome in terms of cost and time the most and is therefore essential in the whole operation.

It is therefore possible to estimate the cost of a project accurately and to manage it in order to stay with in budget.

Most definitely here will be environmental impacts caused by the construction of dams. Some of these are that the dam will be an obstacle and can hinder the flow of floating debris; nutrients and solid matter and floods may no longer occur or would be minimized in size. There can be effects on the climate and earthquakes and landslides can occur because of the dam. Other effects that it has are the drying up of rivers and the changes in the water table.

When looking at all of the above mentioned impacts dams may have on the environment it seems catastrophic for the environment. However most of these impacts can be minimized or avoided completely. This can be done by designing for these problems or managing it to minimize the effect it will have on the environment.

On the other side there are the financial positive impacts that the construction of dams would bring. No economy can grow and enhance the quality of life for all of its people if there is not sufficient water for all. This would include from domestic use such as cooking and cleaning, irrigational uses for food production to the industrial uses and electricity generation.

Besides the providing of water to the nation and the industries there are other positive contributions that dams also will have on the economy. This can include water for irrigation that insures food production and the generation of electricity in a more environmental and sustainable manner in the form of hydroelectricity and dams that could control or minimize the effects that floods can cause.

Irrigation dams provide water for agriculture that ensures for more reliable food production. In the study it was how every clear that the cost recovery of these dams were very poor but that most irrigation dam projects funded by government was not aimed at cost recovery and that the food production and the positive impact that the agricultural sector gets from the dam is its main concern.

Dams used to generate hydroelectricity in most instances were financially viable and cost recovery is easily achieved. Therefore in many instances hydroelectricity is used to in a way fund the project that could also provide water for industrial use or for irrigation. Hydroelectric projects are therefore a good option to make a project financially viable.

As for flood control dams the benefit that the dam holds in ensuring floods will not cause great damage is substantial. In some instances land can be gained from flood plains and further enhance the economical benefits brought about by dams. It should however be stated that the management of the flood control systems is essential.

If combined the economical benefits that the construction of dams would have is massive and overshadow the negative aspects of environmental impacts.

The alternatives to dam construction that were studied are the following: desalination and artificial recharge schemes.

Desalination uses sea water. It is because of this reason that it will mostly be economical for cities such as Cape Town and Durban. The down side of desalination is that it is very expense because it uses the latest technology and a lot of electricity. The greatest contributor to the high cost is energy. However with new technology such as hydropower and solar power which is renewable energy this cost can be reduced substantially. These two energy resources should still be developed and introduced further in South Africa and this may take some time.

The artificial recharge schemes uses different methods to recharge the under ground water. Because South Africa obtain a lot of its water from aquifers it is important to try and recharge the under ground water. This is an expensive method and complicated system that needs a great deal of effort and knowledge.

The alternative methods studied show that there are some methods that can be used. Economically, desalination would only be opted for at coastal areas and as for artificial recharge scheme the method will be expensive and complex and the runoff water from precipitation would be competed by existing or new dams and this method. Therefore dams would still be the most suitable method in providing water for South Africa especially the inland provinces and metropolitans such as Johannesburg.

The question whether dams are the best solution for the supply of water for South Africa can now be answered. When taking into consideration facts such as the economical benefits that the construction of dams will bring, it clearly weighs heavier than the negative aspects such as the cost of the projects and the environmental impacts, especially because these negative aspects can be controlled or avoided as mentioned earlier. There are also not alternative techniques that really can be said that it can solve the problem.

6.3 Conclusion

From the above it is clear that if one takes all that has been said previously that dam construction is still the best option for South Africa's growing water demand. This assumption can be made because the cost of the projects can be calculated accurately and during the construction phase the cost can be managed. The environmental impact can also be minimized or avoided and there are not alternative techniques that can be used with great confidence especially in Gauteng, Limpopo and North West provinces. The positive economical contribution that the construction of dams will have is massive and there are options such as hydroelectric projects that could help in the cost recovery of dams.

In conclusion the main hypothesis was solved and the study indicates that dam construction is still the best method in ensuring water security for South Africa.

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