Optimised Maintenance - The design of a Management Information System for the Department of Water Affairs

By

Mantsiri Mathabatha Mabala

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Executive Summary

The Department of Water Affairs' (DWA) management has established that the monitoring of maintenance performed on its mechanical and electrical components on a number of assets is not entirely satisfactory. The department aims to improve this situation in a manner that will bring the greatest value at a reduced cost to the organisation.

The purpose of this project is to refine the already existing maintenance and refurbishment process and to design an add-on to the system that will help address the problem. The new system must be inline with current industry standards and best practice.

Simple scheduling and monitoring activities are currently performed using a manual system. The need for a digital computer based system arises once the maintenance system becomes more complicated and more demanding. An Information System (IS) has been designed and will be used for information management purposes. By improving the monitoring and control functions, the maintenance manager is thus able to ensure that work orders are actually completed to satisfaction and on time.

The envisaged benefits to DWA are:

- A simpler way of planning and managing maintenance is achieved.
- **Redundant maintenance costs can be eliminated**. Thus reducing the overall cost associated with maintenance.
- Better alignment to and achievement of strategic objectives.
- **Improved control** over maintenance will assist in achieving better operational and budgetary efficiencies.

The use of a Maintenance Management Information System will decrease the effort and increase the value associated with monitoring and control of maintenance by facilitating more effective reporting and decision making. This will improve effectiveness and the efficiency of maintenance within the department.

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List of Acronyms

ARP	Age Replacement Policy
BRP	Block Replacement Policy
CDM	Context Data Model
CIO	Chief Information Officer
COTS	Commercial off the shelf
CSF	Critical Success Factors
DDG	Deputy Director-General
DFD	Data Flow Diagram
DG	Director-General
DSL	Dam Safety Legislation
DSS	Dam Safety Surveillance
DWA	Department of Water Affairs
ERD	Entity Relationship Diagram
FMEA	Failure Modes and Effects Analysis
GUI	Graphic User Interface
HA	Hydraulically Actuated
ICT	Information and Communication Technology
IS	Information System
IT	Information Technology

KPI	Key Performance Indicators
LAN	Local Area Network
MA	Manually Actuated
ME	Mechanical and Electrical section
MIS	Management Information System
MMIS	Maintenance Management Information System
MS	Microsoft
MTTF	Mean Time to Failure
MTTR	Mean Time to Repairs
NWRI	National Water Resources and Infrastructure
PFMA	Public Finance and Management Act
PSP	Professional Service Provider
RCA	Root Cause Analysis
RCM	Reliability Centred Maintenance
ROI	Return On Investment
RPN	Risk Priority Number
SAM	Strategic Asset Management
SD	Scheduled Downtime
SDP	Stochastic Dynamic Programming
TOR	Terms of Reference

UD	Unscheduled Downtime
WMA	Water Management Area

1. Project Background and Description

This project is done for the benefit of the Department of Water Affairs (DWA). This department is responsible for the management of all the water resources in South Africa. The management of DWA comprises of personnel with technical, administrative, financial and regulatory expertise.

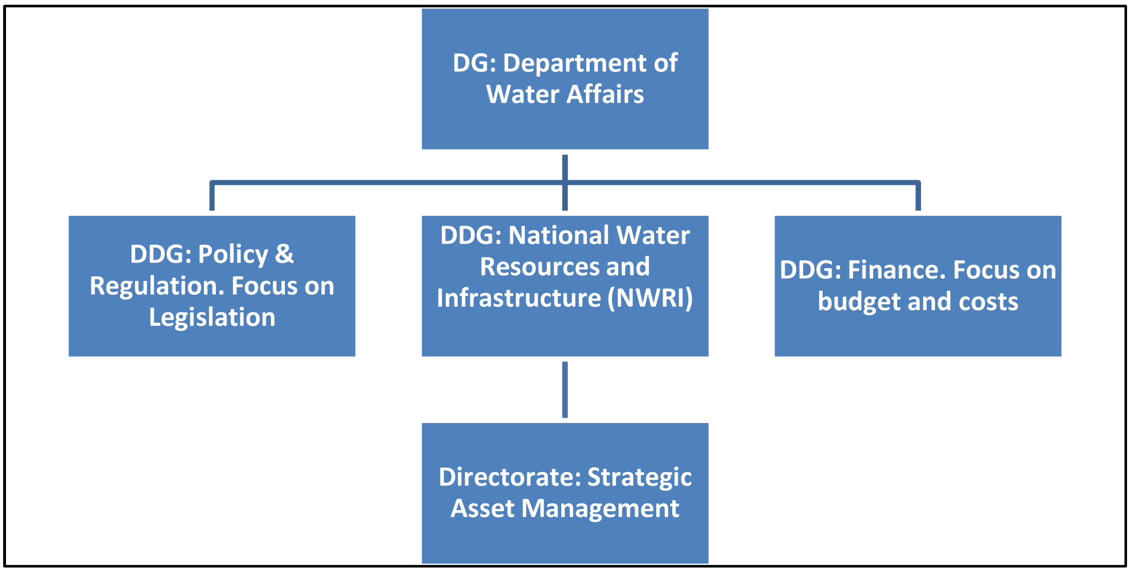

Figure 1: Department sections that have influence on the project.

The National Water Resources and Infrastructure (NWRI) section is regarded as the owner of the majority of the infrastructure it manages. The NWRI section has the authority to decide how dams, pipelines, canals and pumping stations are operated.

This infrastructure which is managed by the NWRI section is worth billions of Rands, therefore the department sees it fitting to continuously improve its asset management strategy. This includes optimisation of inspections, maintenance (both planned and unplanned) and refurbishments.

DWA management has established that the monitoring of maintenance done on its Mechanical and Electrical components on a number of assets is not entirely satisfactory. A comprehensive assessment to identify optimal operations and maintenance has not been conducted, nor is there a credible maintenance management system in place (Childs & Hughson, 2009). The department aims to improve this situation in an effective and efficient manner.

1.1. Terms of Reference

The purpose of the Terms of Reference (TOR) is to establish what is required by the client (Directorate: Strategic Asset Management and Sub-Directorate: Dam Safety Surveillance) and what will be covered in the project.

The maintenance process is divided into three segments:

1st Segment: Problem identification – Using Failure Modes and Effects Analysis (**Not part of this scope**).

2nd Segment: Repair or replace decision – Using Reliability Centred Maintenance, Stochastic Dynamic Programming and Optimised Route Selection (**Not part of this scope**).

3rd Segment: Follow-up and reporting – Using an Information System.

Data is released and captured from each of the three segments. A team working on maintenance of an asset will capture data during an inspection and use that information later on to conduct the maintenance.

An Information System (IS) should be designed for information management purposes. This information will be used to aid the monitoring and control of maintenance activity. The maintenance team should be able to extract information from the Information System and use that information to optimise the output from maintenance activities.

Note: In this report, asset refers to a dam, canal, pumping station or pipeline and not a specific piece of equipment or component. The equipment and components that will be evaluated form part of the assets that are referred to in this report.

Maintenance is used as a generic term to include planned/unplanned maintenance, repair, refurbishment and renewal, and provision for replacement of the infrastructure (Wall, 2008).

A category classification based on size and potential hazard is used to distinguish between the conditions and requirements to be adhered to, and are more stringent and comprehensive for large and high hazard dams (DWA, 1998).

2. Project Aim

The purpose of this project is to refine the already existing maintenance and refurbishment process and to design an add-on to the system. The new system must be inline with current industry standards and best practice.

Once the process has been refined and we are able to measure its performance, reporting and monitoring of the results will take place. This will be done using a Maintenance Management Information System (MMIS) which will provide reporting based on previous and current maintenance activities.

The MMIS should also enable management to plan and manage concurrent maintenance and refurbishment work orders performed on the different assets in the future.

3. Assumptions

The assumptions under which the project is conducted are meant to remove any ambiguity or confusion which may exist. The following assumptions should help understand why certain decisions were made:

- Faults on equipment will be identified visually with the aid of photographic and video equipment. This may result in possible human and machine error.
- The equipment/components will be tested under normal operating conditions.
- DWA uses standardised equipment/components on the majority (> 80%) of their assets. (Gates, Valves etc.)

4. Project Scope

The following points need to be considered when developing the Information System and they will form part of the project scope:

- The project will look at category 1 to 3 dams (where 1 is for small dams, 5 – 12m high and 3 is for very large dams, higher than 30m), pipelines and pumping stations in South Africa. (Dams which are less than 5m high are encountered and they are classified internally as category 0 dams by DWA)
- The maintenance will be done on critical components and equipment. The criticality is based on possible costs which may be incurred and the component's risk profile.
- Input data will be collected during physical inspections.
- Inspection sheets will be created to be used for data capturing in the maintenance optimisation project. The sheets will not be the only hard data collection instrument (see Assumptions).

A set of Key Performance Indicators (Planning and Management) will be defined so that they can be used in future to evaluate how successful the department is in optimising the use of scarce resources.

An Information System (possibly in the form of a database) will be designed to assist in monitoring, reporting and controlling the maintenance process.

The Information System must meet the following requirements:

- It should give accurate reports.
- It must have a simple, reliable and user-friendly interface.
- Automation of the system should be programmed by the designer.
- To enable continuity of use, the Information System should be accompanied by a user manual.

5. Method and Approach

In the first phase of the project, steps are taken to initiate the project. The project environment is evaluated and the client communicates their requirements of the desired product. The next step is problem identification. As part of project planning the roles and responsibilities of each individual are assigned. The project schedule and budget are also agreed upon by both parties. To gain a better understanding of the project (environment and content), information gathering is a critical task that should be carried out in this phase.

The second phase deals with design of the IS. The functional requirements of the new system are determined. The two main deliverables in this phase are the conceptual design of the system and the alignment of the design to the user requirements and specifications.

In the final project phase, the last four steps (completion, implementation, evaluation and hand-over) are followed. The most important deliverables in this phase are the practical application and evaluation of the end product.

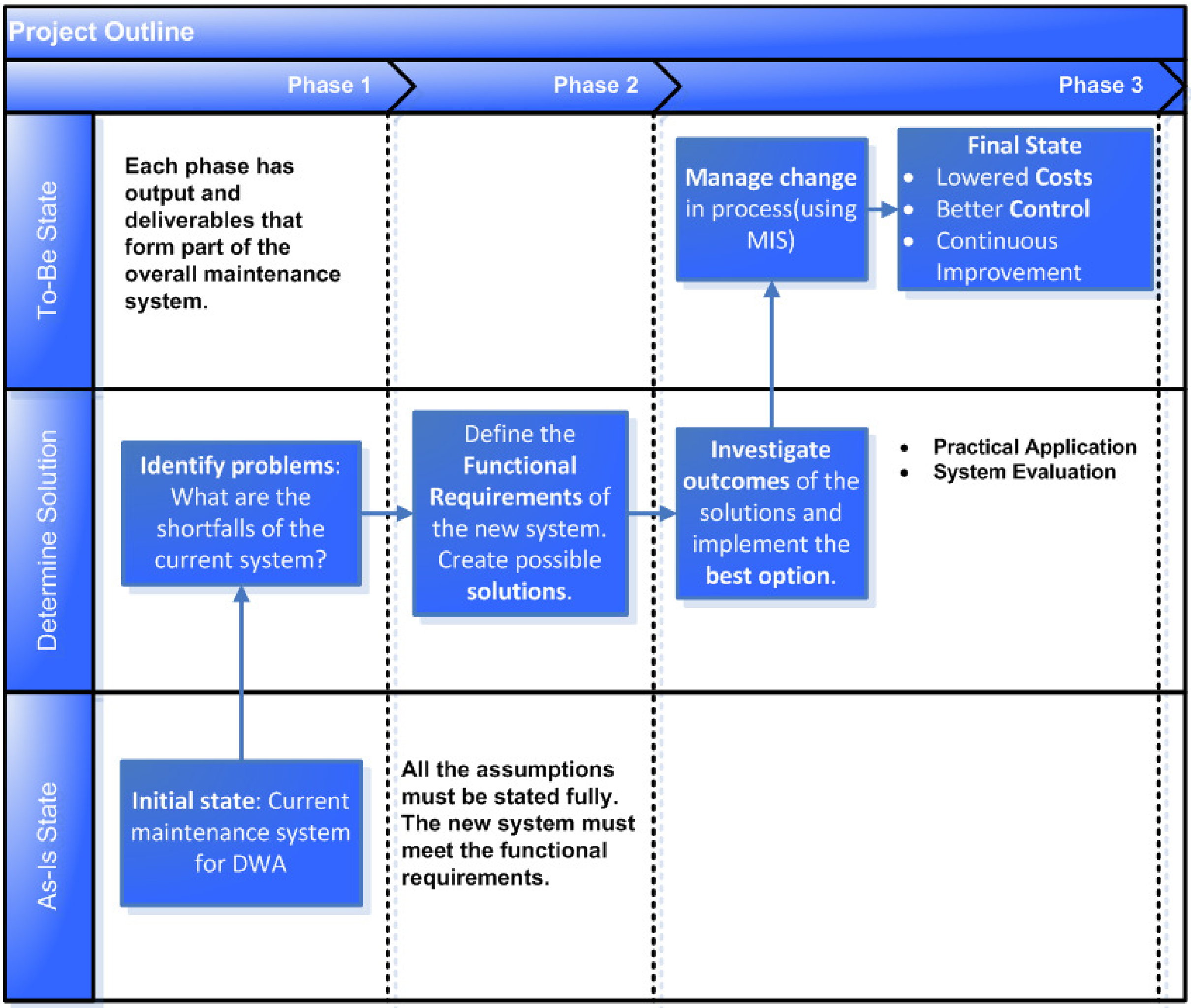

Figure 2: The project outline.

6. Information Gathering and Literature Review

To prepare for the project comprehensively, a literature review has to be carried out. The information gathered made a contribution to completely understanding the problem, grasping all the concepts and terminology and also selecting the appropriate solution to the problem.

6.1. Sources of Information

Various sources of information were considered for input during the project phases, but the following sources proved to be the most helpful:

6.1.1. Published Books

Books give a basic theoretical view on how to tackle practical problems. The following topics were researched:

- Information System Design
- Operations Management
- Maintenance Management
- Research Methods

6.1.2 Published Journals

Journals give a reputable research-based opinion on an exact or similar topic. Even though the researcher might be knowledgeable in the topic, the content is only limited to what he/she thinks is appropriate. Therefore, journals should be consulted with objectivity and care.

6.1.3. Previous Projects and Theses

Previous projects have covered some of the topics which form part of this project's scope. Some of these projects will be used as references for insight where necessary.

6.1.4. Dam Safety Legislation

The Dam Safety Legislation and The National Water Act were used as regulatory guidelines.

6.1.5. Internet

Some of the information used for research purposes was sourced from the internet. Availability and ease of use are the biggest motivation for using the internet as a research aid.

6.2. Maintenance Management

The option of replacing infrastructure once it can no longer serve its purpose is appealing; but it is not always the most cost effective option. The more frequent a piece of equipment is used, the more susceptible it is to failure. When analysing this failure, the type of equipment, its age and condition are taken into consideration. The maintenance team also has to decide what constitutes failure, what consequences may follow and also what mitigation plan to implement.

Maintenance actions are aimed at minimising failure and the consequences of failure (Alsyouf, 2009). As a support function, maintenance should rehabilitate, restore infrastructure and also increase customer value. Once the infrastructure is restored to its normal performance level, effort should be made to improve on that performance.

The identification and implementation of the appropriate maintenance policy will enable the managers to avoid premature replacement costs, maintain stable functional capabilities and prevent the deterioration of the system and its components (Alsyouf, 2009).

Monitoring and evaluation processes must be implemented and strengthened with mechanisms for feedback to result in the necessary desired improvements. In this way, performance change can be measured and the attention concerned can be drawn to non performance (Wall, 2008).

6.3. Performance Management

Performance Management is a strategic and integrated approach to increasing the effectiveness of organisations by improving the performance of the people who work in them and by developing the capabilities of teams and individual contributors (Armstrong & Baron, 1998).

Performance Management was initially used for employee evaluation purposes. The principles of this method are not just restricted to this field and can thus be applied to other fields of interest. This includes the maintenance function, which does not exist in isolation within the organisation. To ensure that set goals and objectives are reached and maintained, controls have to be put in place to measure the system's performance. Once the system output has been measured, action can be taken to remedy the situation in the case of non-conformance or to continually improve a system that is working properly.

Performance objectives within an organisation are different for the organisation as a whole, the constituent departments and the business processes that are used within the organisation. The desire to optimise the use of the three most important resources available (time, money and human capacity) is similar to the need for continuous improvement. The shared characteristic of these three resources is that they can all be quantified and therefore measured.

Performance measurement is used when there is a need to compare actual performance to the required performance. The difference between these two figures gives an indication of how well the system is performing and how far the organisation is in meeting these goals. Key Performance Indicators (KPI) can be defined by the organisation. These KPI are then able to tell management exactly what they need to know about the system they are analysing. By making use of performance measurement methods, the organisation is able to move the system from a state of being dysfunctional to being fully functional. This has the potential to increase efficiency and effectiveness when the desired output is obtained from the system.

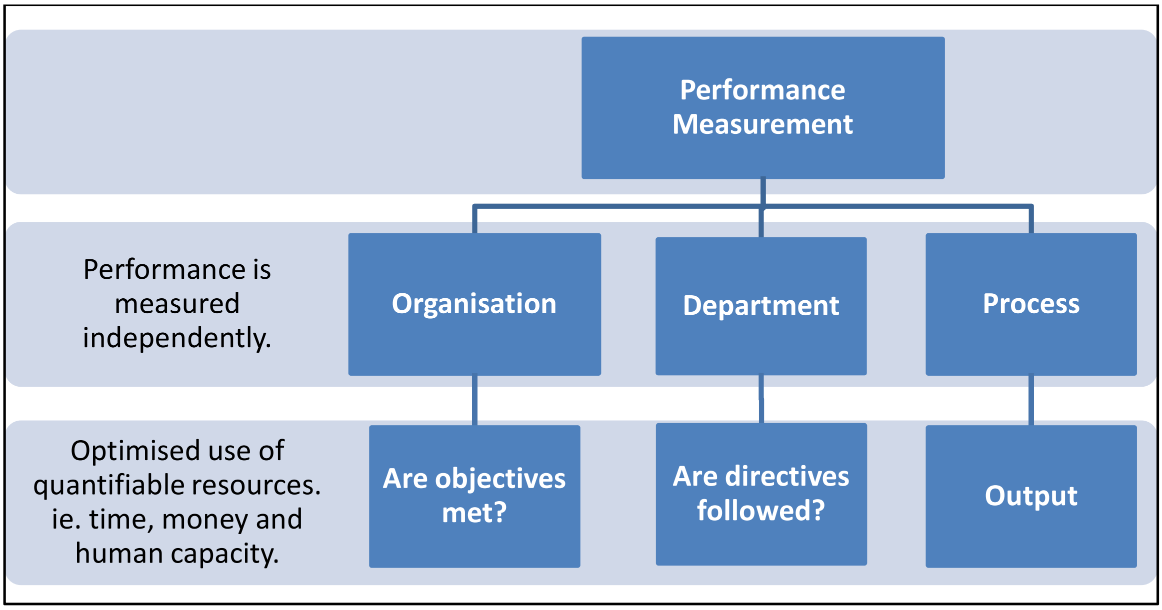

Figure 3: Performance Measurement within an organisation.

The follow-up element of performance management requires that an audit be performed on the system. Assuming that the problem has been resolved, the organisation is able to compare the desired state with the system's actual state. The onus is on the organisation to work towards the desired state by managing the continuous improvement initiatives that are needed.

Performance management and measurement has its roots in employee evaluation, but its principles can be adopted for use in assessing systems which are used within the organisation for as long as their output is quantifiable. This management tool can be used by the organisation in striving for never-ending continuous improvement.

6.4. Key Performance Indicators

"It is not possible to manage what you cannot control and you cannot control what you cannot measure." – Peter Drucker

In a manner similar to that used in quality control, Key Performance Indicators (KPI), much like process capability indices are used to measure the process' actual performance relative to the required performance. The KPI selected will be able to track cost, downtime, work execution and follow-up, number of failures per asset (where applicable) and overall asset performance. Although ideally failures should be identified and prevented before they occur; they sometimes occur randomly without any warning signs. The number of such failures also needs to be monitored. Any unusual trend or behaviour should be analysed and measures should be taken to minimise the probability of future failure occurring.

6.4.1. Planning Key Performance Indicators

The following KPI will be used to assess the overall performance of the maintenance on the assets from a planning point of view:

- Number of days scheduled downtime (SD)
- Number of days unscheduled downtime (UD)
- Percentage total downtime (per year)

$$Percentage\ total\ downtime = \frac{SD + UD}{365}$$

An indication of the relative amount of time an asset spends not working properly allows the maintenance team to plan the amount of resources they can allocate to maintaining the asset. Once the performance is understood, resources are allocated and problems are resolved, the team can start working on ways to reduce downtime.

6.4.2. Management Key Performance Indicators

The following KPI will be used to assess the overall performance of the maintenance on the assets from a management point of view:

- Total maintenance cost per asset (this is a cumulative yearly cost and can be used to see how much the department has spent at any point in time on maintenance of the asset)
- Percentage maintenance cost per asset

$$Percentage\ Maintenance\ cost\ = \frac{\sum Maintenance\ costs}{Asset's\ replacement\ value}$$

- Number of failures per asset
- Mean Time To Failure (MTTF)
- Mean Time To Repair (MTTR): The aim is to bring this number down. If this number goes down then both KPI for downtime will go down.
- Percentage of maintenance work orders completed on time: The longer an asset remains un-repaired, the more damage it may suffer from not working as it should be. More damage generally translates into more costs.

The above KPI should to be moved to an optimum level. Once that level is reached, they should be monitored and controlled for change.

6.5. The Use of Information Systems for Monitoring and Control

When dealing with data and human performance one should build in sufficient checks to ensure that errors or deliberate malpractices do not go undetected (Willemse, 1990).

Simple scheduling and monitoring activities are currently performed using a manual system. The need for a digital computer based system arises once the system becomes more complicated and more demanding. To a certain extent, an integrated maintenance system that incorporates both daily maintenance tasks and long range planning depends on an automated database of facility information (Mearig et al, 1999).

The system user must be able to enter data into the database, and then he should be able to use the database to extract relevant information regarding maintenance activities. The database should simplify the scheduling and monitoring function of the maintenance system. For DWA, maintenance activity is performed over long periods of time; therefore only monthly and yearly tasks should be considered.

6.5.1. The Process of Creating an Information System

The design process described by Bentley and Whitten in the book *System Analysis and Design for the Global Enterprise* was adopted. This process is described in the following sub headings:

6.5.1.1. System Initiation

The initiation of the project has been covered and is referred to in the project scope and TOR. The scheduling and budget requirements were discussed in the project proposal. (**Appendix A**)

6.5.1.2. System Analysis

Requirements Discovery and Analysis

- To establish the requirements of the IS, the client and project manager were interviewed. The information collected from the interviews was analysed and a more refined set of requirements resulted. This set was limited to what is feasible, based on the project constraints (time, money, human capacity).

Use-case Modelling

- Use-cases are used to model the system requirements.
- Use-cases describe the system functions as viewed by the user in a manner and terminology that they can understand (Bentley & Whitten, 2007).
- The objective of constructing the requirements use-case model is to elicit and analyse enough requirements information to prepare a model that communicates what is required from a user perspective (Bentley & Whitten, 2007).

Data Modelling using an Entity Relationship Diagram (ERD)

- ERD depicts data in terms of the entities and relationships described by the data (Bentley & Whitten, 2007).

Process Modelling and the use of the Data flow Diagram (DFD)

- DFD depicts the flow of data through a system and the work or processing performed by the system (Bentley & Whitten, 2007).

6.5.1.3. System Design

The transfer from paper to an actual code takes place. The conceptual design of the MMIS is used to create the actual computer based system (database). The product has to meet the requirements discussed in the scope and TOR.

6.5.1.4. System Implementation

To complete the design process, the practical use and application of the IS has to be corroborated. The first version of the design will be evaluated. Subsequent versions should incorporate solutions that address any deficiencies that were discovered.

Functional compatibility and integration should be followed by acceptance and use by the client. The product should be accompanied by a User Manual once it is ready for use.

6.6. Summary of Literature Review

The main function of maintenance is to restore infrastructure. To do so, an understanding of the equipment and the system as a whole is necessary. To facilitate and ensure effective accomplishment of the organisation's goals, the system and its stakeholders have to be managed. These goals include both strategic and operational objectives. If improvements to the monitoring and control functions within the system are made, a further contribution will be made to optimising the maintenance activities.

7. Conceptual Design and System Analysis

An Information System is more than just a product of technology, its is primarily a tool that serves the goals of the organisation by helping turn concepts and ideas into something the organisation can use (Bentley & Whitten, 2007).

7.1. Requirements Business Case

"There is a need to record data related to each and every critical component on an asset (dam, pipeline, pumping station). The recorded data should give an idea of the condition the component is in. When performing maintenance activities, it may be beneficial to record each work order that will be completed. This may include a description of the task and the party/entity that will be responsible for completing the work order.

The records may be used by the maintenance manager as a reminder of when the work orders should be completed. A note of the next scheduled activity (inspection or service) should be *made. All records of maintenance activity should be filed by date; starting with the current date so as to alert the maintenance manager to what needs to be completed within a given year, month or week. Once the work is completed, it should be noted on the record."*

The above requirements business case will be used to come up with the main concept for the IS. Any additional concepts and ideas that will follow will be derived from the feedback received after testing the IS and evaluating its performance in addressing the problem.

7.2. Stakeholders of the Information System

The following stakeholders of the system were identified:

System Owner(s):

- Minister: Department of Water Affairs
- Deputy Director-General: National Water Resources and Infrastructure
- Director: Strategic Asset Management (SAM)

System User(s):

- M Mabala (Internal user): Department of Water Affairs
- M Motaung (External user): Madikela Engineering Solutions cc.

System Designer:

- M Mabala

The stakeholders will either directly or indirectly play a role throughout the project lifecycle.

The System Designer is generally responsible for:

- Deciding on a language to use for programming the code.
- Sourcing network technology to be used for support.
- The overall design of the database.

The System User will expect:

- The IS to produce reports. The routing of information and reports should also be specified.
- Prescribed policies and procedures to be followed in both use and design of the IS.

The Maintenance Manager should decide on:

- Strategic plans to adopt and follow.
- Ways to maintain a competitive advantage.

As stated in the beginning of this document, finance and regulatory stakeholders are also present within the department. Any solution that is produced as a result of the research and design components of the project has to adhere to Dam Safety Legislation, The Water Act and The Public Finance and Management Act (PFMA).

The public remains a key stakeholder of the project. Any solution that is produced should not in any way compromise the ability to restore assets to a fully functional and safe condition. Such safety concerns even though not explicitly voiced out, will be considered none the less.

7.3. Data Collection and Inspections

A series of visual inspections took place. The purpose of the inspections was to firstly, examine the condition of equipment and components on the various assets managed by the department. Secondly, data was collected and recorded during the inspections. The data will be used to populate the Information System once it has been implemented and is ready for use.

An inspection sheet already exists and is currently in use. To fully support the aim of the project and to extract as much value as it is possible out of inspections and other maintenance activities, it is proposed that a new inspection sheet be created. The new inspection sheet should be able incorporate data that will be used for Failure Modes and Effects Analysis (FMEA), Reliability Centred Maintenance (RCM) and Stochastic Dynamic Programming (SDP).

The following dams were visited and will be used to initially populate the IS during evaluation:

Armenia Dam

- Category 3 Arch dam in Water Management Area (WMA) 13.

Clan William Dam

- Category 3 Gravity-Arch dam in WMA 17.

Gariep Dam

- Category 3 Arch dam in WMA 13.

Ngotwane Dam

- Category 2 Earth-fill dam in WMA 3.

Oukloof Dam

- Category 3 Gravity-Arch dam in WMA 16.

Poortjieskloof Dam

- Category 3 Arch dam in WMA 18.

Roode Elsberg Dam

- Category 3 Arch dam in WMA 18.

Roodefontein Dam

- Category 3 Earth-fill dam in WMA 16.

Van der Kloof Dam

- Category 3 Arch dam in WMA 13.

Welbedacht Dam

– Category 2 Earth-fill dam in WMA 12.

Wolwedans Dam

– Category 3 Gravity-Arch dam in WMA 16.

See **Appendix F** for map of WMA in South Africa.

The data collected during inspections will be used to support a series of activities which must take place. First of all, activities should be planned. To do so, the maintenance team needs to know what needs to be repaired/replaced, the potential risk associated with ignorance of the problem and the level of priority assigned to the problem. Secondly, a schedule of the required maintenance activity needs to be created. The schedule will incorporate the level of prioritisation assigned to a work order and an optimised travel route. The last two activities are execution of maintenance and monitoring of the end result.

The current practise is to record data on an inspection sheet, use the data to compile a Dam Safety Inspection report, decide on what needs to be repaired/replaced and then recording these activities in a log book. This manual form of information management can be considered as a very basic form of an Information System. Part of the purpose of this project is to add-on to the current system, redesign processes where necessary and then make improvements on any short comings that are discovered during system analysis.

7.3.1. First Draft Inspection Sheet

Moving from current practise to an improved state required making changes that will manifest in improvements to the inspections. The first draft of the changed inspection sheet evolved from what is currently been used. Elements of the original sheet that were found to be inherent to most inspection sheets remained in the design. The template of the inspection sheet can be found in **Appendix B**.

The following characteristics can be found on the inspection sheet:

- The sheet is in a check list format.
- The basic condition of most of the critical components will be recorded.
- General comments can be made and recorded on the inspection sheet.
- The original *"yes/no"* format has been maintained in the inspection sheet.

A checklist has limitations because it can only communicate confirmations. Unless the inspector goes into detail (not mandatory), an individual reading such a sheet will have limited information to use and will have to rely on assumptions going forward.

7.3.2. Second Draft Inspection Sheet

An overall understanding of the fact that not all maintenance work orders can be completed simultaneously is very important. By establishing and utilising proper prioritisation methods for maintenance activity, more can be accomplished to restore the assets to their original and safe condition. This issue is not addressed in the first draft of the inspection sheet. Before activity can be prioritised, the risk associated with ignoring the discovered fault/break-down has to be understood. High-risk faults will always be assigned high priority by the inspector and maintenance manager.

The second draft inspection sheet can be used to influence asset management (component name and description), resource allocation (time, money and human capacity needed) and whichever scheduling strategy the organisation chooses to adopt. The template of the inspection sheet can be found in **Appendix B**.

The following characteristics were identified on the inspection sheet:

- A full description of the condition of the component can be recorded.
- Recommendations can be made on the inspection sheet either immediately or at a later stage.

- Any work in progress taking place can also be noted.
- The age and operational status of the component/equipment can be recorded.

A decision to replace or keep a component will be influenced by whether it's fully operational, safe, effective and efficient. If the component is found to be out of order, not performing its specified duty (not effective), posing a potential hazard or costly to operate; a decision to either repair or replace it will be made.

7.4. Use-case modelling

Logical design is a component of System Analysis and Design where business requirements are translated from written and spoken user needs into inputs for a system model. Once the requirements have been identified, use-cases can be used to trace their fulfilment through the project lifecycle. The use of Use-case modelling facilitates and encourages user involvement; this is one of the primary critical success factors for ensuring project success (Bentley & Whitten, 2007).

The user of the IS should be able to perform the following four activities:

- **Create** a record.
- **Read** component/equipment information.
- **Update** component/equipment information.
- **Delete** a record that no longer exists or has become insignificant (non-critical).

To translate these activities into use-cases, the analyst has to determine who the event initiators are, who/what triggered the events and also how the system would react to the events.

The following system actors will initiate and also receive information from the Use-cases:

- Maintenance Manager
- Additional IS User

– Time
– SAM

The Use-case model diagram that has been designed has three sub-systems. The sub-systems are categorised into inspection, maintenance and asset management sub-systems. Each sub-system has its own Use-cases; however, an actor can have influence on Use-cases from different sub-systems. In the initial analysis stages, the focus was on how the system will function as opposed to the actual design of the system.

7.5. Process Modelling

To identify where the MMIS would feature within the maintenance function, the current process (As-Is) has to be analysed fully. Changes to the current process may be required. Key opportunities have to be identified and fully exploited to ensure that maximum gain can be obtained from the project.

The maintenance process has internal processes which need to be identified, isolated, analysed and optimised. This will require a lot of input from SAM and other stakeholders within the department.

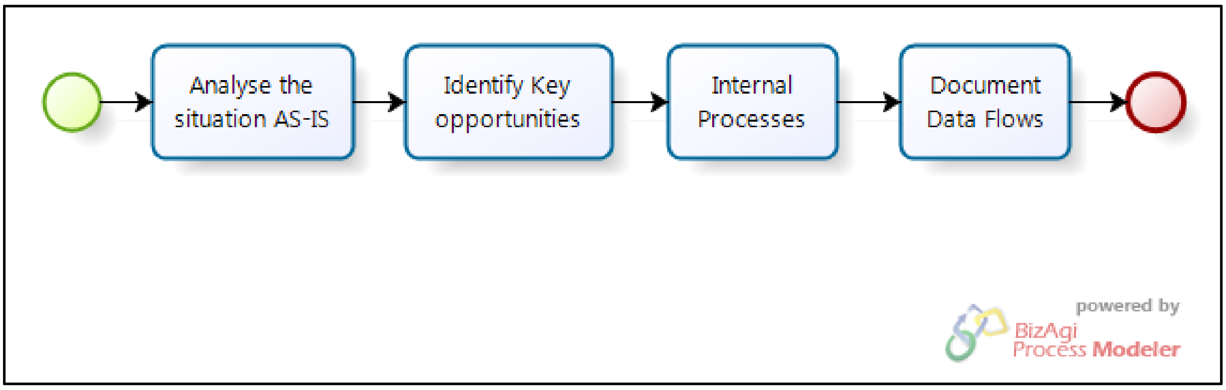

Figure 4: The process redesign sequence.

Lastly, the flow of data within the Mechanical and Electrical (ME) section will have to be documented. The suggested flow should be used as guidance and followed by those who will be handling the data. The routing of reports will also be defined.

7.6. Data Modelling

The maintenance activity performed will be based on data collected after an inspection. An inspection can be scheduled and planned or unplanned and reactive. Planned inspections will be performed according to a predetermined schedule. Unplanned inspections are reactive and will be performed before maintenance can be conducted in order to assess the extent of the damage caused.

In essence, a valid assumption can be made that maintenance is based on the inspection and what information is discovered during the inspection. When analysing an inspection, the attributes we are interested in are the component that is being inspected, the scheduled time for the inspection, the entity that will perform the inspection and lastly the resulting maintenance activity that is recommended after the inspection.

The Star Schema below is used to model the relationship between the Inspection table and the other related tables. The inspection is viewed as the fact or a known certainty. This is an element of the entire process that must be present. The other four tables are dimensions of the Inspection table. The Primary Keys of the other tables become attributes of the Inspection table and when grouped together are now referred to as Surrogate Keys. The behaviour of the table is what gets identified during an inspection and the required action that must be taken after the inspection.

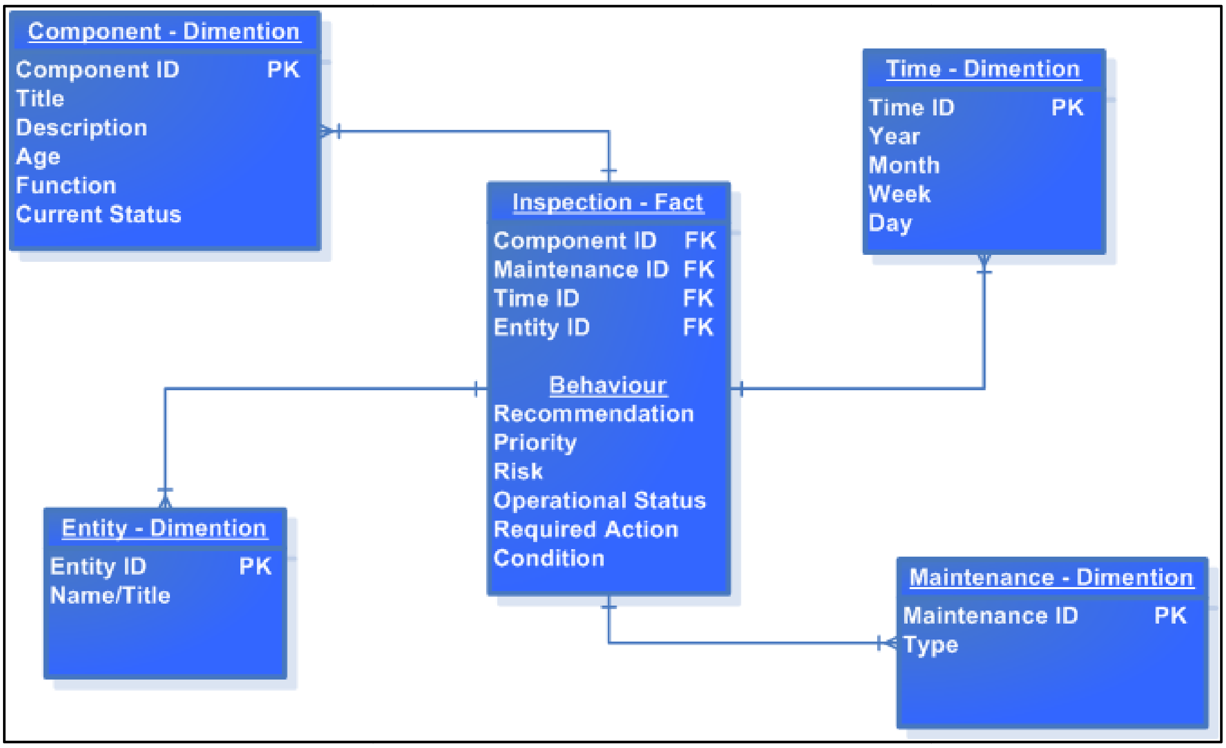

Figure 5: The Star Schema.

The following relationships between the tables are present:

– A (one) type of inspection (Scheduled Planned or Unplanned Reactive) can be performed on one or many components.
– A (one) type of inspection (Scheduled Planned or Unplanned Reactive) can be performed at one time or on many other frequent occasions.
– A (one) type of inspection (Scheduled Planned or Unplanned Reactive) can be performed by one or more entities.
– A (one) type of inspection (Scheduled Planned or Unplanned Reactive) can result in one or many types of maintenance.

The Star Schema is a data model that simplifies how relationships are modelled. This diagram can be used at a glance to develop concepts of relationships that will exist within the IS. A

"Snowflake diagram" (ERD) is more detailed and should be constructed once the concepts have been developed.

8. Design and Specification of the Information System

System design is the specification of a detailed computer based solution (Bentley & Whitten, 2007). A critical deliverable of system design is designing the Use-case, Process and Data models. These models are a description of the way the system behaves and how the different entities within the system relate.

8.1. Use-case Modelling

The Project Scope, TOR and Aim described the goals that the system aimed to achieve. The Use-cases will be used to describe a sequence of activities and user interactions that will be encountered in the pursuit of accomplishing the system's goals.

The Use-case diagram below indicates who the actors are and how they will interact with and influence the system. The manner in which the system responds is represented by what the users receive from the system. A more detailed description of the Use-cases has been provided in the narratives that make up **Appendix D**.

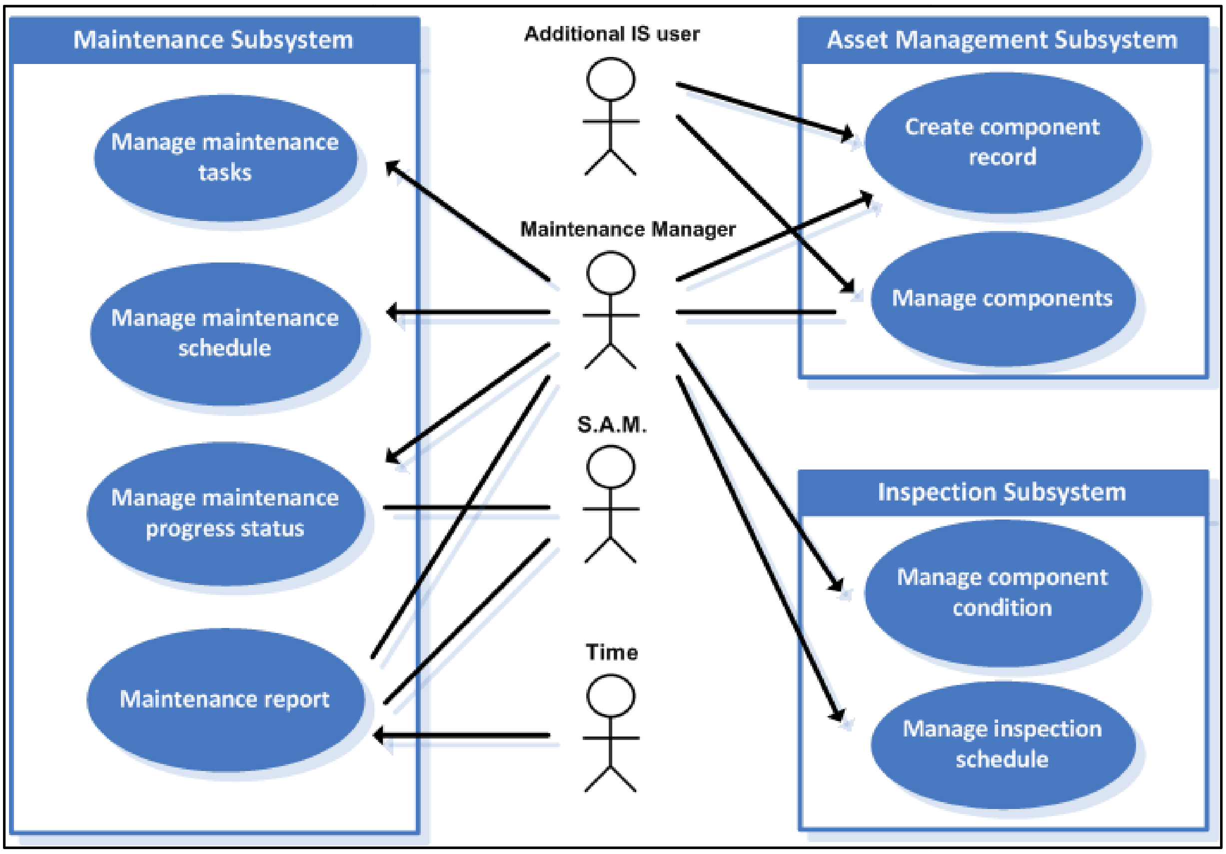

Figure 6: The Use-case diagram.

8.1.1. Use-cases

The following Use-cases were identified and will be used during system analysis and design:

Create component record

– Create a record of a critical component.

Manage components

– View the components captured in the database.

Manage maintenance tasks

– Record the specific tasks that need to be performed on a component that is found on an asset.
– Assign an entity to maintenance work.

Manage maintenance schedule

– Manage the sequence of maintenance activity.

Manage maintenance progress status

– Manage the progress status of maintenance that is either pending or complete.

Maintenance report

– Produce the monthly maintenance report.

Manage component condition

– Update the component's condition.

Manage inspection schedule

– Manage the sequence of inspections.

8.2. Process Modelling

Process models and Data Flow Diagrams (DFD) will be used to document the sequence of activities in the system. The models and diagrams form what will be the redesigned processes and subsequent data flows.

8.2.1. Maintenance Processes

The current maintenance process diagram, pictured below, has very basic elements which feature in most maintenance processes. The planning function is responsible for the preparation and allocation of facilities and resources respectively. The relevant stakeholders have to ensure that plans are in place to pave the way for subsequent maintenance activity.

The department has adopted a reactive approach to maintenance. This means that any action taken will be a result of what is discovered during an inspection or after extra-ordinary failure occurs.

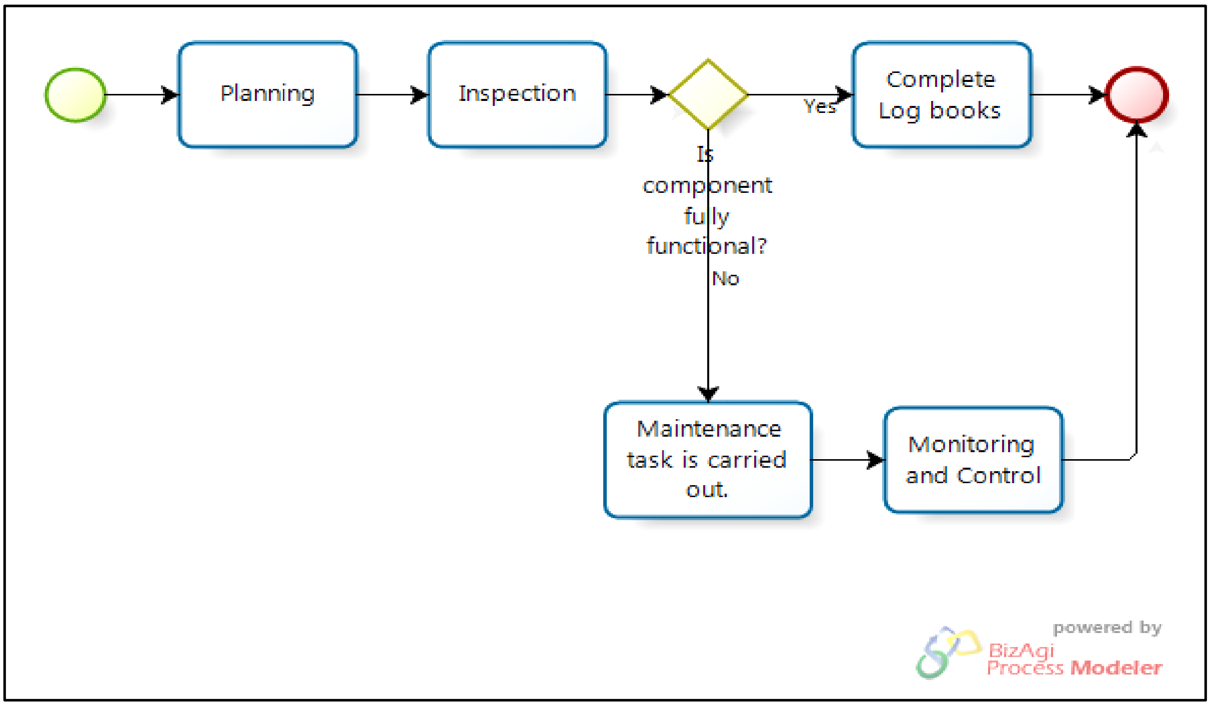

Figure 7: The basic maintenance process.

The monitoring and control function within the process should exist, ideally, but it is often neglected in a number of organisations. This has also been noticed within the department. It has been discovered during inspections that some work orders are not completed within the prescribed time frame and some recommendations are not considered.

Organisations are constantly realising that the majority of the business processes they follow are becoming inefficient and outdated. This has resulted in renewed interest in streamlining these business processes (Bentley & Whitten, 2007). To do so, the existing business process is modelled, analysed and if needs be, redesigned to incorporate improvements.

The above process model which represents the current maintenance process has been refined and redesigned. Additions have also been made and data storage has been incorporated into the new process model below. The redesigned process model will make it easier to construct the DFD because of the similarities between the two diagrams.

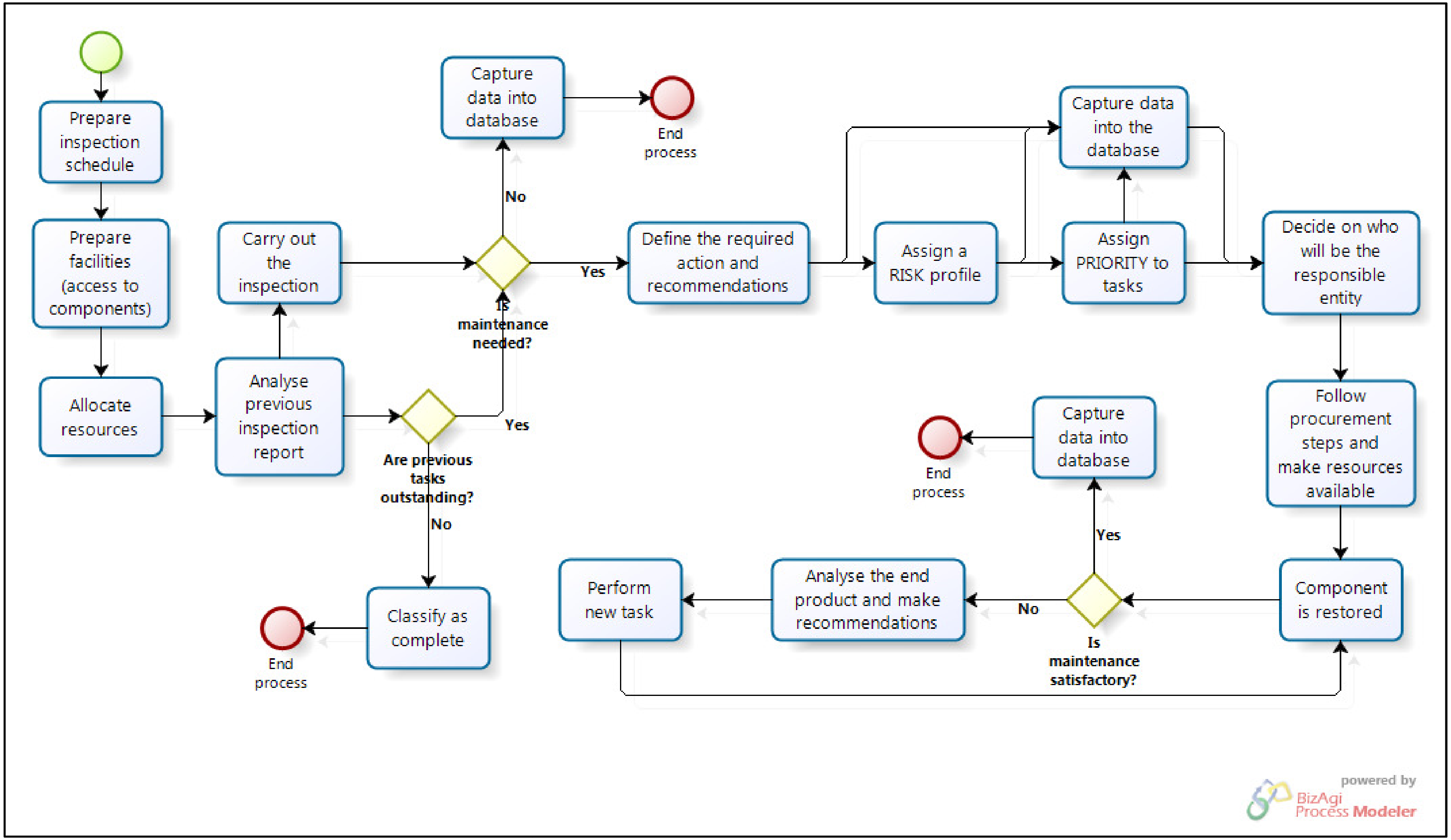

Figure 8: The redesigned maintenance process model.

8.2.2. Data Flow Modelling

The flow of data and information through the system is represented by the Data Flow Diagram (Bentley & Whitten, 2007). The diagram can also be accompanied by a description of any additional processing that is performed by the system.

This representation of reality can be either based on an existing system, where the model will help the analyst to gain better understanding of the system, or on a proposed system. When modelling a proposed system the DFD will accompany system requirements and documentation of the technical design.

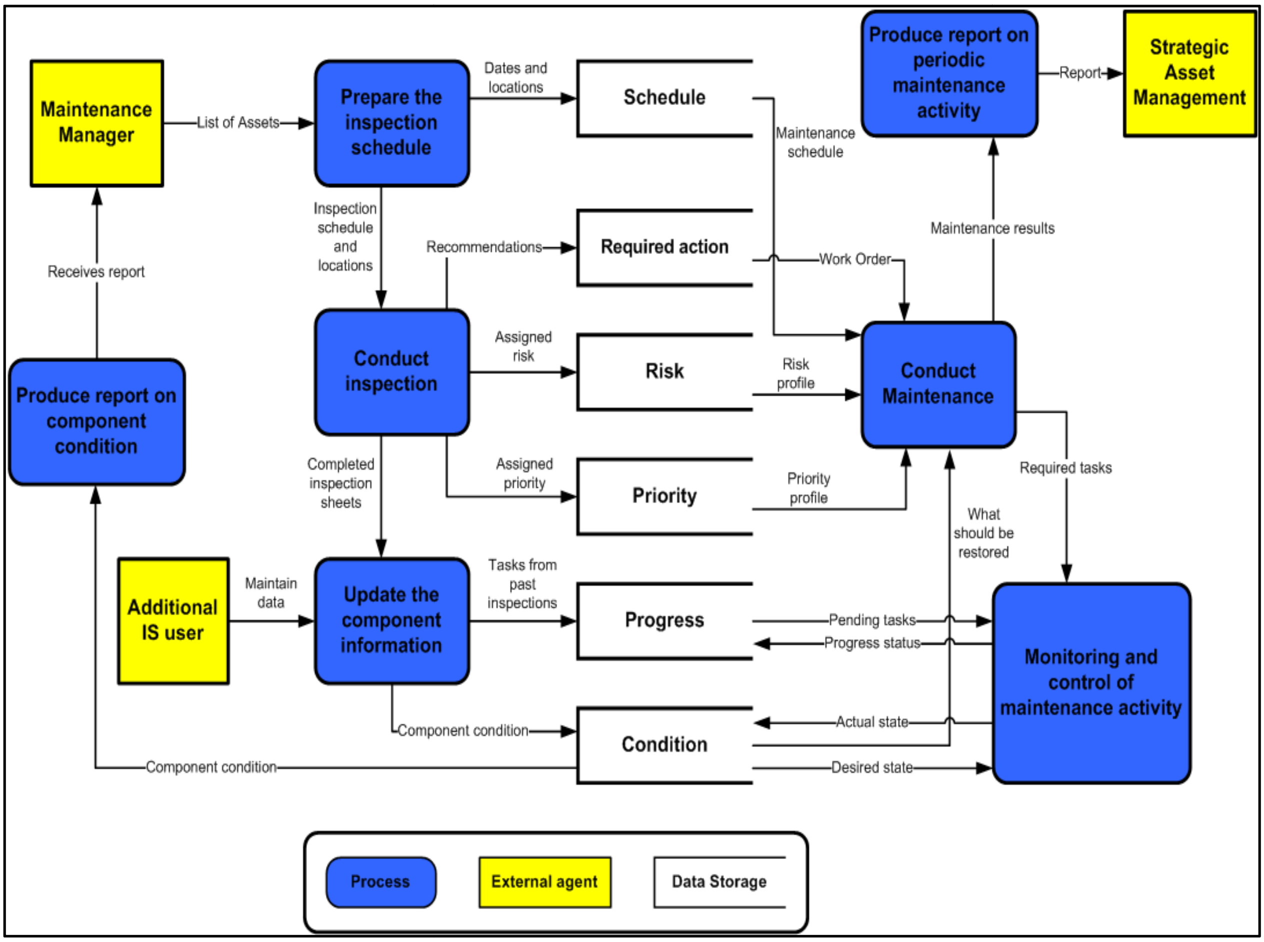

Figure 9: The Data Flow Diagram.

The above DFD shows the flow of maintenance related data within the IS.

8.3. Data Modelling

Data modelling is a technique that can be used to organise and document a system's data. System models make a considerable contribution to systems development and eventually evolve and are implemented as databases (Bentley & Whitten, 2007).

The Entity Relationship Diagram (ERD) will be used to model the data. This data model uses different notations to depict data in terms of the entities and relationships represented by the data (Bentley & Whitten, 2007).

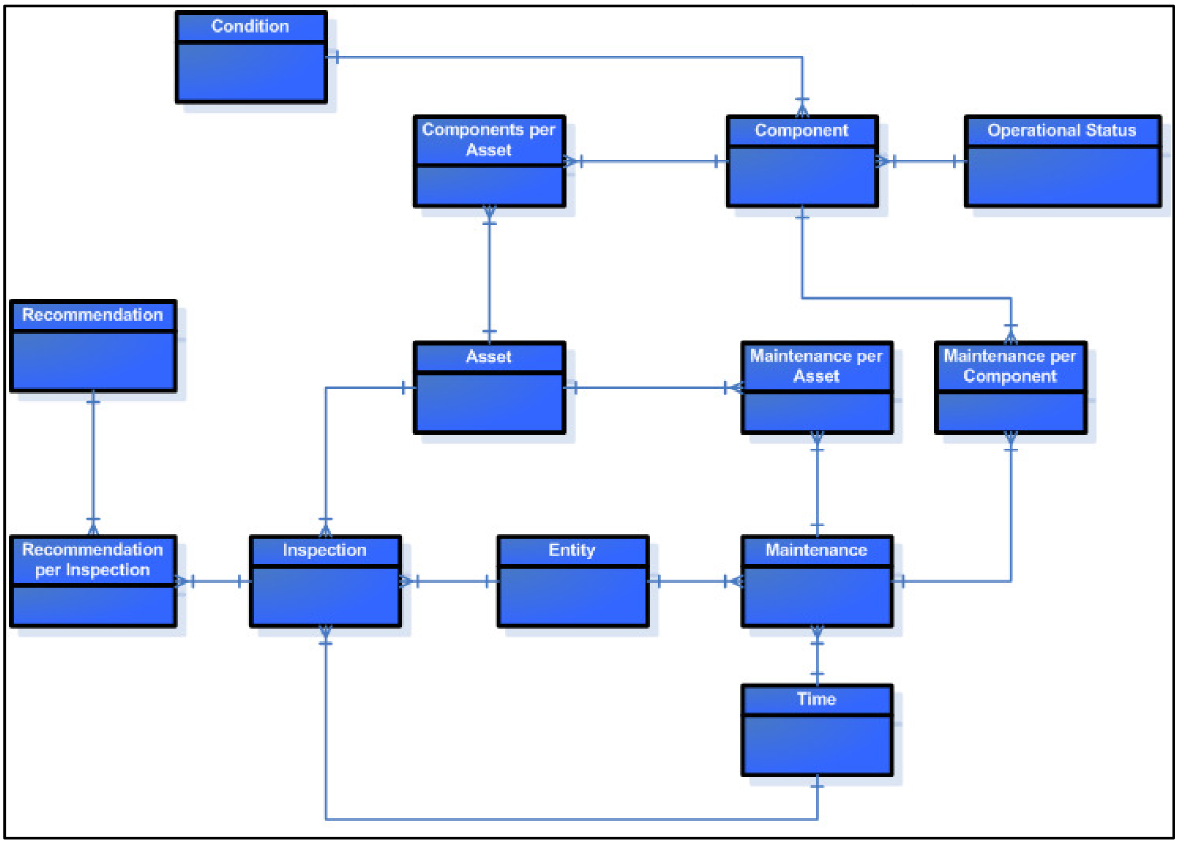

Figure 10: The Context Data Model.

The Context Data Model (CDM) is basically an ERD without the attributes. The above CDM was used to refine the scope and to gain better understanding of the system. The aim is not to go into detail about the entities but to rather focus on the business rules and associations that are found in the system.

The table named "*Entity*" represents any one of the following stakeholders:

- An individual (Engineer, Technician etc.)
- A contractor
- A DWA management region
- SAM
- NWRI

There should not be any confusion between what is represented in the table and an entity that is essentially something about which the organisation stores data.

The complete, attributed Entity Relationship Diagram can be found in **Appendix E**.

8.4. Construction of the Information System

The core of the MMIS will be a computer based database. The database will maintain information relating to maintenance activities performed on the different assets. Features which are built into the system should be able to improve operational productivity and the execution of certain jobs.

The maintenance team has the following three options available to them for constructing the MMIS:

- Commercial off the shelf (COTS) package
- DWA In-house design
- Design by a Professional Service Provider (PSP)

The selected option should be able to assist in managing maintenance operations. It should also support good, structured decision making.

8.4.1. Commercial off the shelf Packages

A number of off the shelf software packages are available on the market and could be purchased for use in managing the maintenance activities. These packages are dependent on availability and budget constraints.

When choosing a COTS software package, the following should be considered:

- Who are the manufacturers and where are they situated. Software manufactured by international manufacturers could be less accessible and more costly.
- The product specifications. These specifications will allow the buyer to assess how well the product matches the system's specified requirements.
- The prices of the available software. A balance between cost savings and quality of software has to be maintained.
- The chosen package has to meet most, if not all, of the specified requirements.

Software packages can be either custom made or industry specific, depending on who the manufacturer/vendor is.

A good software package should offer the following characteristics:

- It should release maintenance activity status reports.
- It should be able to produce summaries of completed maintenance activities in report form.
- It should be able to perform job scheduling and resource allocation.
- It should keep records of equipment functions and brief specifications as provided by the manufacturer.

8.4.2. DWA In-house Construction

In-house design of the MMIS enables the maintenance team to control what goes into the design of the MMIS and what output will be generated. The design and construction is carried out based on the requirements set out by the stakeholders.

For a competent MMIS to be constructed, the project manager has to ensure that the department's Information Technology (IT) infrastructure and capabilities are adequate.

The office of the Chief Information Officer (CIO) is in charge of the management of all IT resources. Availability of resources such as personnel, computer hardware and network infrastructure is controlled by this office. To address the previously stated problem, a request for the construction of a MMIS that meets all the system's requirements should be sent to the office of the CIO so that resources can be made available.

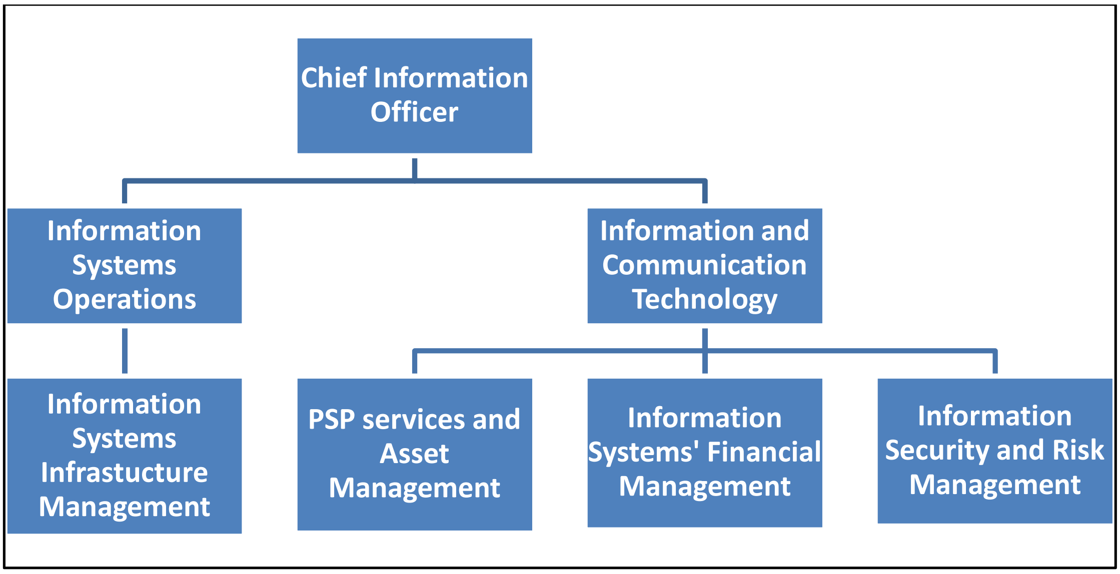

Figure 11: The office of the CIO.

More detailed functions of the office of the CIO include:

- The formulation and implementation of IS operational plans and strategies.
- The office is tasked with ensuring that IS operations are carried out.
- Procurement of the best suited infrastructure and software packages.
- Monitoring of ICT service delivery.
- Ensuring compliance with IS legislation.

Based on the structure, size and detailed profile of the personnel who form part of this office, it can be concluded that DWA has adequate skills and capabilities to construct the IS. However, constraints such as time and business development objectives (appointing a PSP for work, so as to generate income and create business growth within the country) could result in external consultants being alternatively hired.

The following software packages are available for use in design and construction of the MMIS and can be purchased by the office of the CIO:

Microsoft Access 2003/2007/2010

Microsoft Access is a database design and construction software package. This software is easily accessible and it comes standard with the MS Office suite. Its popularity is based on the fact that MS Access empowers you to make the most of your information by making the information easier to view, analyse and to maintain.

Most recently in the 2010 package, MS Access amplifies the power of the user's data through newly added web databases which make it easier for the user to monitor, track and produce reports. It creates a platform for the user to share information with other stakeholders within the organisation.

MS Access will be used to create a prototype of the database. The prototype is a basic representation of the final product and is in no way presented as the final solution to the problem.

The benefits for using the MS Access software package are:

- It is easily available.
- It allows the IS designer the ability to design and build databases faster and easier.
- The designer can use it to create more impactful forms and reports.
- The designer can add automation and complex expressions without writing a line of code. This is a huge benefit for a new user who is recruited without being very knowledgeable about the database's original construction.
- The user interface allows for easy access to the right design tools.

The estimated cost for the MS Office Professional suite is $499.99. This translates into an estimated cost of **R 3,479.00** (at an exchange rate of R 6.96 per $1 on 01/01/2010).

http://office.microsoft.com

MySQL Enterprise

MySQL Enterprise is a recent version of the world's most popular open-source database creation software package SQL Server. It is a comprehensive offering of production support, monitoring tools, and MySQL database software. The software package delivers optimal performance and reliability within a secure operating environment.

It significantly reduces the risk, cost, and time required to develop, set up, and manage business-critical information systems. When using the software package, the user can receive monthly security updates and quarterly service packs in order to maintain the safety of the IS.

www.mysql.com

Oracle Database Software

Oracle Database 11*g* Standard Edition is a database for relatively small servers. It includes Oracle Real Application Clusters for higher availability and is simple to manage. It is upwardly compatible with the more advanced Oracle Enterprise edition which is an alternative option when the database grows in size and proportion.

The benefits for using Oracle Database software packages are:

- As a user you are able to improve quality of service with enterprise-class performance, security, and availability.
- It can be run from a computer which has a MS Windows or Linux operating system.
- It has automated, self-managing capabilities.

The estimated cost for this software is $350.00 per user. The package allows for a minimum of 5 users, therefore the minimum total estimated cost will be $1,750.00.

This translates into a minimum estimated cost of **R 12,180.00** (at an exchange rate of R 6.96 per $1 on 01/01/2010).

www.oracle.com/za

8.4.3. Professional Service Providers

The third option is to outsource the design and construction to external Professional Service Providers (PSP). The selection will be made following a pre-set procurement procedure. The main assessment will be based on availability of the PSP, the consultants' capabilities and the overall cost for the project.

The following consulting companies are available and capable of providing the services required by the department:

- Accenture www.accenture.co.za
- IBM www.ibm.co.za
- RDB Consulting www.rdbconsulting.com
- The Integrated Solution Group www.isgdatabasedevelopment.com
- Deloitte www.deloitte.co.za
- Digiterra Architecture and Consulting www.digiterra.co.za
- Umbrella ICT www.umbrellaict.co.za

Once the choice has been made to appoint a PSP, the terms of reference for the project will be finalised and the job will be advertised on tender. The department's normal selection procedure will be followed and the best bid will be chosen based on the price, the company's profile and most importantly, on whether the PSP will be able to create an IS that meets the department's requirements.

8.4.4. Preferred Option

The three construction alternatives were evaluated, and based on their characteristics a preferred option was identified.

The table below was used to compare the alternatives. The evaluation was based on cost implications, the need for additional infrastructure and the availability of after sales support from the service provider.

	C.O.T.S Package	DWA in-house design	Design by a PSP
Cost	Cost of software and once-off installation. Future upgrades will also result in additional costs.	Once-off software cost, cost for future upgrades and an additional year salary for a permanent programmer **(R200 000)**.	The lowest quote was provided by Umbrella ICT for **R35 000**. Includes construction, testing and training.
Infrastucture and resource requirements	Computer hardware, network infrastructure and internet access.	Computer hardware, network infrastructure and additional personnel in the form of a programmer.	Computer hardware, network infrastructure and internet access.
After sales support	Availability of support will vary between the vendors. This is mostly provided at an additional cost. Communication will be via the internet for international vendors.	The department has a LAN Administrator who can provide the support. Once the programmer is hired, he will also maintain the IS on a regular basis.	After sales support is optional and comes at an extra cost. Most PSP design the IS in such a way that only they can provide after sales support and maintenance on the system.

Table 1: Comparison of IS construction alternatives.

The best alternative for DWA would be to have an in-house design. The initial cost implications are higher, but can be justified over time. Once the programmer is hired, he is not restricted to working solely on the MMIS. He can be assigned to other projects in order to maximise his productivity and return on investment (ROI).

The department will always be in control of the construction process and will ultimately own the IS completely (owning the design of the IS and the product itself).

9. Practical Application of the Information System

The proposed MMIS will be made available to the maintenance team as an add-on to what is currently been used. The intention is not to have just a list of assets which can be viewed by the maintenance team, but rather to have a structured framework in place for decision making.

It should be kept in mind that the expected life of infrastructure has been estimated as low as at component level and ranges from 10 years (for some small motors) through to 300 years (for some dam walls). Most of the current assets owned by the department (> 75%) were constructed in the period between 1960 and 1990 (Childs & Hughson, 2009). Dam Safety Inspections take place in 5 or 10 year intervals.

9.1. Context of the Information System within maintenance

One of the objectives of the project is to develop a framework which enables consistent, dependable and optimal decision making. Throughout its entire lifecycle, a component will undergo periodic maintenance, refurbishment (renewal of parts) and upgrading to ensure that it meets its functional requirements.

The deliverables from the project will be used to influence or as input for the three segments of maintenance (Problem identification, Repair or replace decision and Follow-up). To put this into context, a brief discussion of the activities that will take place will follow.

9.1.1. Problem Identification

The new inspection sheet will be used to record the relevant data during physical inspections. The condition of the component/equipment will be assessed and a decision will be made as to whether further action needs to be taken.

In order to identify potential failure modes and to determine the effect that they may have on the operation of an asset, Failure Modes and Effects Analysis (FMEA) will be used. The function of FMEA is not just to identify what might go wrong, but to also capture historical data for use in the future.

The three types of FMEA that are relevant to the scope of this project are:

- Design FMEA, which focusses on components within the asset and subsystems.
- Process FMEA, which looks at the maintenance process as a whole. This is usually used to identify and deal with any defeciencies that are present in the maintenance process itself.
- System FMEA, which looks at the global system functions and it includes input from the Design and Process FMEA.

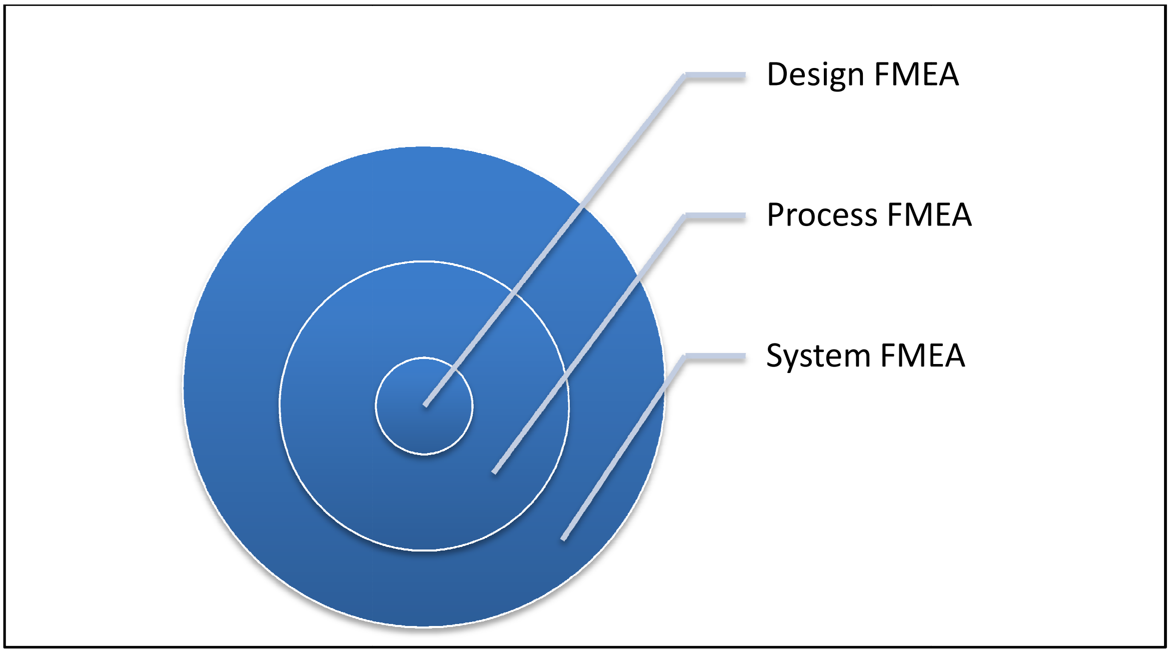

Figure 12: The three types of Failure Modes and Effects Analysis.

The following procedure should be followed when carrying out the FMEA:

Step 1: Review available documentation on the asset.

Step 2: Determine the potential failure modes for each critical component by inspection.

Step 3: Record the possible effects of each potential failure mode.

Step 4: Assign a severity rating for the failure modes.

Step 5: Determine the probability of the identified failures occurring.

Step 6: Determine the probability of a defect being detected before it results in failure.

Step 7: Calculate the Risk Priority Number (RPN) for each failure mode and related task.

Step 8: Prioritise the maintenance work orders which need to be completed.

9.1.1.1. Calculating the Risk Priority Number

The following calculation is used to determine the RPN:

$Severity\ (S) = Consequence\ of\ failure\ (Rating\ from\ 0 - 10)$

$Occurrence\ (O) = Probability\ that\ failure\ will\ occur$

$Detection\ (D) = Probability\ that\ a\ defect\ is\ detected\ before\ failure\ occurs$

$$RPN = S * O * D$$

Severity

The severity rating can be considered entirely subjective. This rating is assigned by the inspector or the maintenance manager. A set of guidelines will have to be defined to ensure that this rating is assigned correctly.

Occurrence

The probability that a failure will occur can be calculated and estimated using past information and trends that have developed. The responsibility of calculating this figure will have to be delegated to an individual working in the section.

Detection

The possibility that a defect will be detected during an inspection can be calculated and estimated using past information and trends that have been discovered. As with the probability of failure, the responsibility of calculating this figure will have to be delegated to an individual working in the section.

The failure modes with the highest RPN are given the highest priority. The exception would be in cases where the severity of a failure mode is high, but the associated RPN is not the highest. In such a case the failure mode with the extraordinarily high severity rating will be given highest priority.

A FMEA will not be conducted as part of this project scope, but deliverables from this project will support the FMEA; basically, the inspection sheet will be used to collect the data and the MMIS will be used to store any relevant output that is generated by the FMEA (Prioritisation of work orders etc.).

9.1.2. Repair or Replace Decision

A decision will have to be made as to whether a component is repaired or replaced. This decision will be influenced by the condition of the component and the economic implications of the decision.

Once the work orders have been prioritised, they will be scheduled. The schedule will be managed with the help of the IS. Work orders should appear chronologically, starting with the current date so as to alert the manager to what needs attention. In addition to the use of the

MMIS, the use of a predictive modelling technique will have to be evaluated by the organisation.

The output of a predictive modelling technique precedes a decision to either repair, in the case of minor failure, or to replace components, in the case of major failure. If the component is replaced, a normal Age Replacement Policy (ARP) is used or a Block Replacement Policy (BRP) is used.

Age Replacement Policy: The component is replaced at failure or at the end of a specified service life.

Block Replacement Policy: The component is replaced at failure or at times $k*T$ *(k = 0, 1,…., n)*; whichever comes first. It should be noted that a component is not replaced at a scheduled replacement time if its age $< T$.

The methods of Dynamic Programming will be used to support Condition Based Maintenance where the aim will be to steer clear of unnecessary repairs and refurbishments. Since functional component failure usually occurs in a stochastic manner, Stochastic Dynamic Programming (SDP) would be ideal in solving this type of maintenance problem.

The following equipment can be maintained using a SDP supported refurbishment strategy:

- Pumps
- Generators
- Motors
- Components with relatively small service lives (1 – 5 years)

The behaviour of these components under operation results in failure that can easily be modelled with SDP to find the optimal maintenance strategy (cost wise). If failure occurs, it will be recorded during inspections and FMEA. These records will be stored in the IS. If a trend develops, SDP will be used to model the failure. The output of the SDP will help predict when failure may occur and then steps can be taken to mitigate the risk of that failure.

9.1.3. Follow-up and Reporting

The best way to trace maintenance work orders is to firstly, know who has been assigned the work order, secondly, when the work order must be completed and most importantly, what the specific task is. The maintenance manager should have access to this information when he needs it.

The Information System will address the above requirements by keeping a record of the work orders that have to be completed (description). Each work order will be assigned a maximum time frame for completion (maximum 1, 2 or 5 years) depending on the associated risk profile of the component (low, medium or high). The maintenance manager will be able to track the progress made on the work orders and to also know how much of the allocated time has elapsed and how much time remains.

9.2. Benchmarking

Performing prioritised maintenance tasks requires the correct focus on what has to be done, supported by well designed processes and information flows. Few organisations have the correct structures in place to support this scenario.

A recent international study was commissioned by the Water Services Association of Australia into decision making frameworks for the maintenance of sewer mains by 23 water utility authorities in New Zealand, Australia, Canada and the UK. The results of the study led to the conclusion that the risk identification and analysis decision making processes used by DWA are comparable with international best practice (Childs & Hughson, 2009).

However, there are some areas of maintenance that still need attention. Areas of improvement include:

- The use of predictive modelling techniques such as Stochastic Dynamic Programming.
- An improved condition assessment technique should be developed.

The current weakness in the DWA maintenance function and its processes is the prioritisation of the maintenance and rehabilitation tasks that are needed across the organisation.

It is envisaged that the MMIS will assist in resolving these problems and also bring about the desired improvements by supporting and facilitating maintenance improvement initiatives.

9.3. Critical Success Factors

A Critical Success Factor (CSF) is an element that is characteristic to an organisation and its initiatives. It can be used to ensure that the organisation is successful in reaching its objectives.

The identification of CSF can aid the organisation to focus its attention and resources on what actually matters and what will bring the most benefit. The benefit of making use of CSF is:

- CSF can be communicated effortlessly.
- They can be used to monitor how well the organisation is performing and how close they are in achieving their objectives. CSF can also be easily monitored to see if they are still applicable throughout the project.
- CSF can be used to support strategic planning.

A Critical Success Factor is not a Key Performance Indicator (KPI). Critical Success Factors are elements that are essential for a strategy or initiative to be successful. KPI are measures that quantify objectives and are used to measure performance of strategic initiatives (Du toit, 2008).

The Critical Success Factors for the Maintenance Management Information System (MMIS) are:

- The MMIS receives general acceptance from all active stakeholders.
- The users are involved in the design and implementation of the MMIS.
- The new processes and system are considered easy to use, understand and implement.
- The source and accuracy of input data can be validated (effective use of reliable inspection sheet).

- MMIS output can be used to increase customer value (improve safety of assets by improving maintenance on the assets) at a lowered cost to the organisation.
- Maintenance is easily auditable.

9.4. System Integration

Time is the only real measure of sustainability for any project; therefore it remains to be seen whether the MMIS will continue to be in use even after a change in personnel. But none the less, the design has to incorporate certain features that will support continuity.

A major justification for the use of the system is its ability to remove the pain away from performing maintenance admin jobs such as data capturing and reporting. The design of the IS ensures that information is received, processed and presented in a structured manner that is essential for effective planning and management of maintenance.

Planning needed for completing maintenance work orders

From a planning perspective, the following inputs will always be essential in establishing a good maintenance policy:

- Costs of previous work orders. The costs will contribute to future budget considerations.
- List of components and equipment. Planning should go hand in hand with asset management.
- Historical data and developed trends.
- Product information and specifications.
- Prioritisation of activities. The prioritisation will ultimately affect the optimised routes developed for performing inspections, periodic service and condition based maintenance.

DWA management has established the need for improved maintenance practices. The planning phase of maintenance is essential in guaranteeing that work orders are completed. By making improvements to the planning aspect and establishing a structured way of planning for maintenance, the department will ultimately improve its maintenance practices.

Management of maintenance activities

It is the responsibility of the maintenance manager and the maintenance team as a whole to ensure that maintenance is managed properly. This includes allocating all the resources necessary for completing work orders and also ensuring that the work orders are actually completed.

The MMIS has built-in elements which will assist in managing the following key maintenance attributes:

- Cumulative and once-off costs associated with maintenance. By identifying areas of repeated failure (keeping records of component failure when it occurs) the maintenance team can isolate those elements that cost the most to maintain.
- Relative condition of the components before and after maintenance is completed. The aim of maintenance is to restore components to their desired working condition.
- Risk of failure due to postponement or negligence of work orders.
- Severity of failure and the resultant consequences thereof.

In the event that the system requirements change as a result of change in users or management, the design may have to be changed. The proposed design allows for future modification to the system and can accommodate any resultant future growth.

The best suited construction option will be one that also incorporates after sales support (IS updating, maintenance and modification) from the software vendor and the system builder.

9.5. Current IS vs. the proposed IS

A comparison was made between the current system and the proposed system. The table below serves as justification for why there is a need to design, build and implement the proposed system.

	Current System	Proposed System
Scheduling	Manual system	Computerised system with pre-programmed automation.
Inspection sheet	Checklist	Detailed inspection sheet which properly support CBM.
Format	Paper based system where data is stored in log books and dam safety reports.	The inspection sheet is used for input into the database. Easy access to information.
Information flow	Not properly documented.	Structured flow of information that is well documented.
Reporting	Manual and paper based. This method is old, but consistent.	Computerised form of reporting that is automatic, reliable and consistent.
Follow-up	Follow-up is very poor. This situation needs to be urgently adressed.	Consistent follow-up which is linked to the periodic reports.

Table 2: Current IS vs. the proposed IS.

10. Evaluation of the Information System

The design process below was followed to ensure that the final product gains acceptance from the users and stakeholders who will be involved in the project. After each deliverable is handed over, the stakeholders were given the opportunity to evaluate what is presented and to make a decision to either proceed with the next deliverable or to make changes to the designs.

The process is iterative with checks and balances at each stage; although the need for formal reviews is not imperative (Blanchard & Fabrycky, 2010). This is owed to the good communication and feedback that was maintained through out the entire design process. The reviews will be carried out continuously until the final solution is handed over to the department.

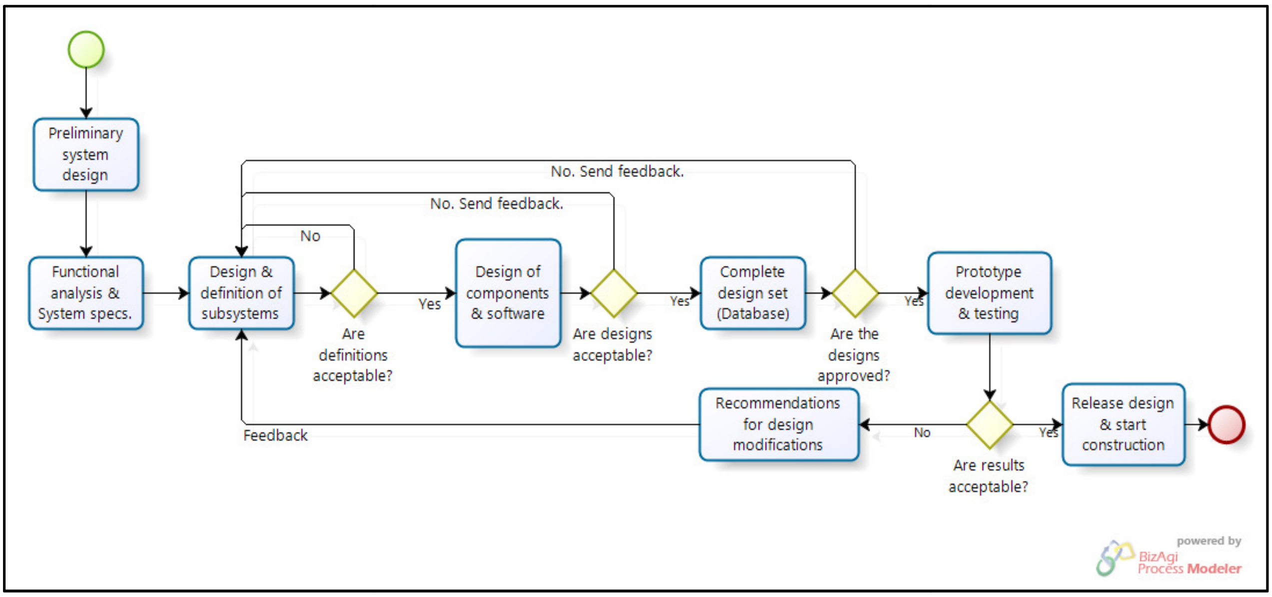

Figure 13: The design sequence with feedback.

The evaluation of each deliverable was documented. These results will be referred to in future if traceability of user requirements and design specifications becomes a necessity.

10.1. Inspection Sheet Template

The inspection sheet template used for maintenance has been redesigned. The newer version of the sheet was used for data capturing during the last inspection that was scheduled for this project (23^{rd} – 25^{th} August 2010).

The data captured during the inspection has been included in this document as **Appendix C**.

The format of the inspection sheet facilitates efficient and effective data capturing. This is mainly due to its user friendly format. The contents of the inspection sheet can be easily transferred onto the database; therefore the template does well in preceding the use of the computer based system for monitoring and control.

An evaluation of the first draft inspection sheet was also conducted. In this template the required input is made in a checklist format. There is no way of establishing whether the identified defects are serious or not. This is the reason why the draft had to be redesigned. The second draft template addresses this situation by allowing the inspector to describe the condition of the component he/she is inspecting.

10.2. Prototype of the Database

A prototype of the database has been created in MS Access. The prototype is a basic representation of the final product and is in no way presented as the final solution to the problem.

The Information System's Graphic User Interface (GUI) gives the user access to three forms which will be used to enter data onto the database. The user will also be able to produce reports in an easy manner, at the click of a button. The GUI is simple, reliable and user friendly. Any required automation has been programmed into the database.

10.2.1. Main Menu Graphic User Interface

The GUI below is designed to help the user navigate around the database. The layout of the GUI was created to meet the following requirements:

- The prototype must have a simple, reliable and user-friendly interface.
- Automation of the database functions should be programmed by the designer.
- Input forms and reports should be easily accessible from the main menu of the database.

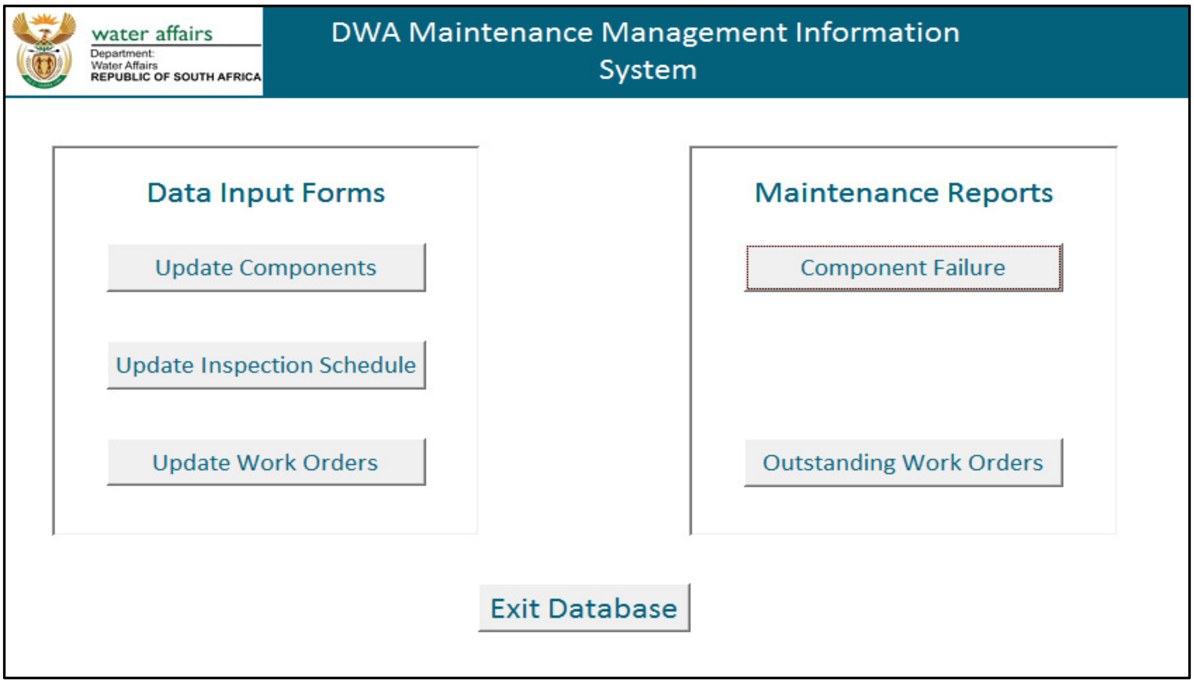

Figure 14: The Graphic User Interface.

10.2.2. Data Input Forms

The following data input forms were created:

- Component Record form
- Update Inspection Schedule form
- Maintenance Activity and Work Orders form

The forms are simple to use and facilitate input of the right maintenance related data. The form's GUI allows the data capturer to navigate between records for easy reference.

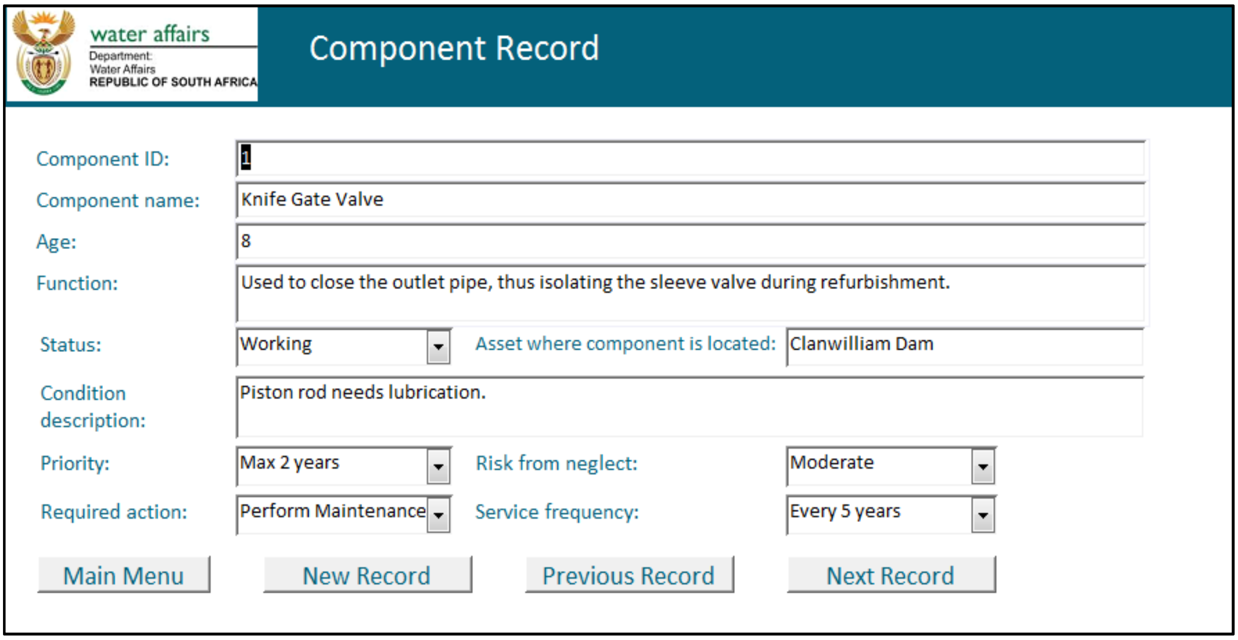

Figure 15: The Component Record form.

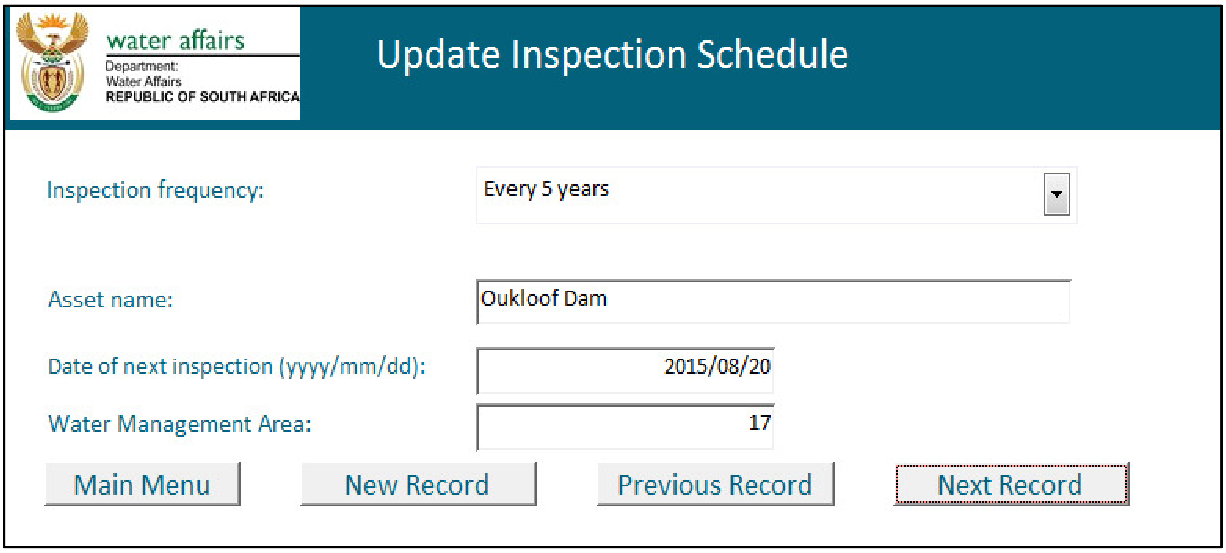

Figure 16: The Update Inspection Schedule form.

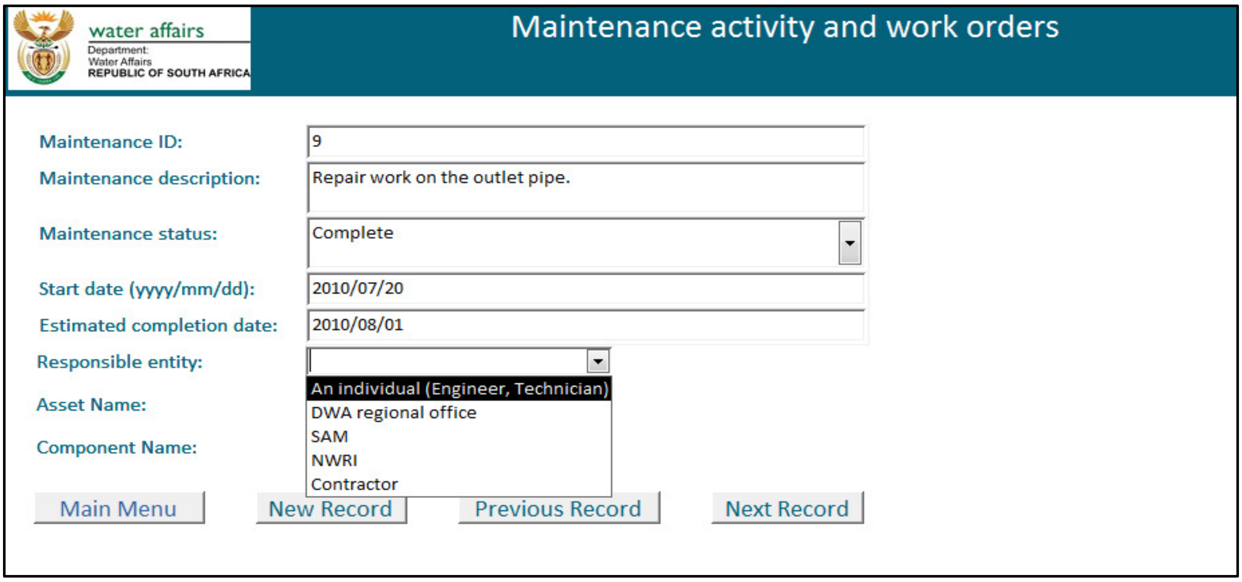

Figure 17: The Maintenance Activity and Work Orders form.

10.2.3. Reports

The following reports were created to assist the maintenance team to monitor maintenance work orders. The reports will also be used to identify components with repeated failure. The effective use of this new reporting format will ensure that the department meets its aim of achieving the greatest value (ensuring that tasks are actually carried out) at a reduced cost (isolating and reducing repeated failure).

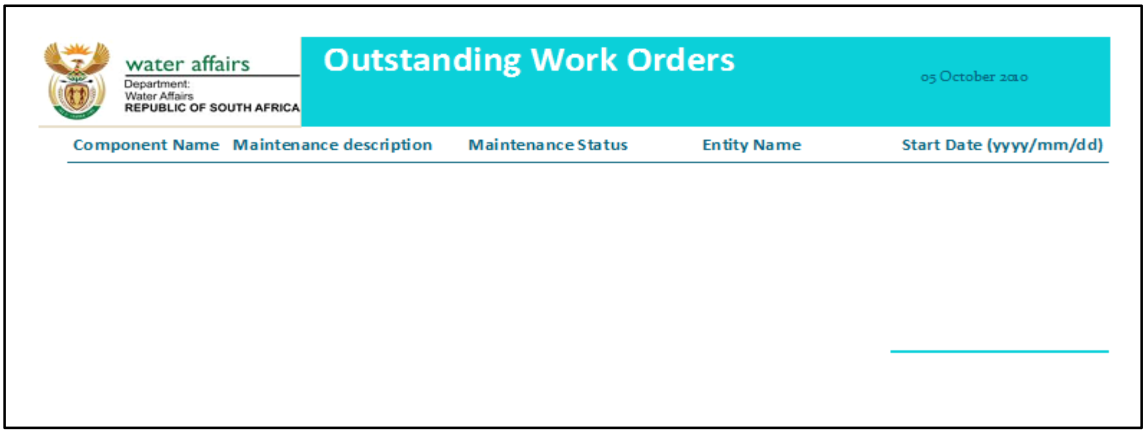

Figure 18: Outstanding Work Orders report.

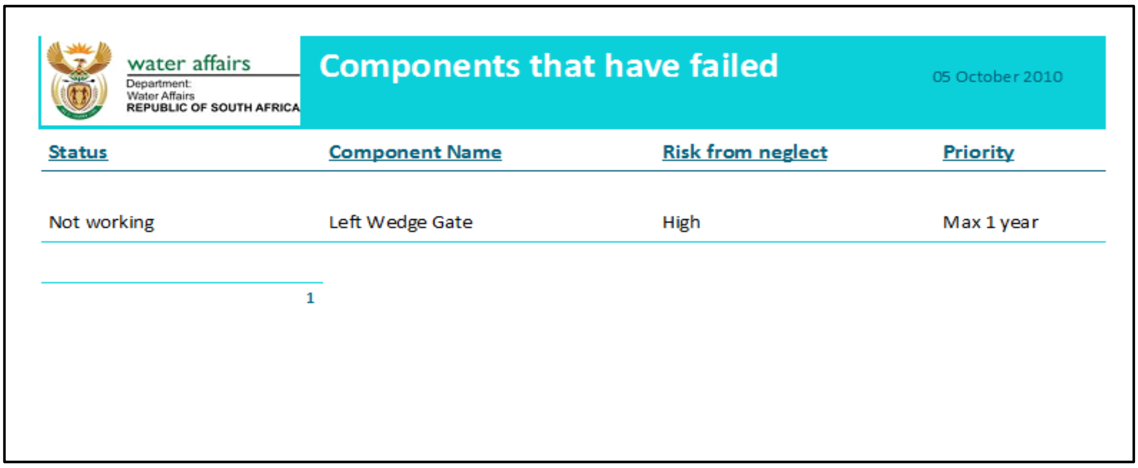

Figure 19: Component failure report.

10.3. Feasibility Tests

The following feasibility tests were performed to assess whether the project is viable or not.

10.3.1. Operational and Schedule Feasibility

The overall project time schedule is 3 years (covers all three segments discussed in the TOR) and the deliverables will be assessed on a continuous basis until they meet the stakeholders' requirements. The design and specifications for the IS will be produced within the agreed upon schedule.

Once the IS has been constructed, roles and responsibilities will have to be filled. All the stakeholders who have been previously mentioned will be available to fulfil the roles and to assume the responsibilities. Personnel and support infrastructure is in place and available for construction to take place.

10.3.2. Technical Feasibility

The software packages needed to design and construct the database are easily available. Infrastructure (computer hardware, internet, servers and a LAN) is in place and can support the potential demand the system will place on it.

10.3.3. Economic Feasibility

The funds needed to cover the initial costs can be made available following the right procedures as per legislation (PFMA). Any additional costs will have to be budgeted for in future. The purchasing of software and other supporting infrastructure will be done following the pre-set purchasing procedure.

11. Conclusion and Comments

An Information System (IS) has been designed and will be used for information management purposes. This Information will be used to aid monitoring and control of maintenance activity. The maintenance team should be able to extract information from the IS. The information can be used to improve the quality of how maintenance is performed.

11.1. Cost Savings

The cost savings from the project cannot be correctly estimated within the given project schedule; therefore a proper analysis of the cost savings is not feasible. The reason for this statement is based on the fact that maintenance requirements differ per asset and per component type and there are over 4000 dams registered with the Dam Safety Office. The large number of assets under DWA management raises a need for the department to create a strategy that will help manage those assets and the associated cost of maintaining them.

For example, by being able to identify components that constantly need to be repaired or replaced we can investigate alternative designs or products that will give better performance. This will reduce the associated costs of maintaining the problematic component by reducing the frequency of maintenance that has to be performed.

Along with an improvement of operational costs, there needs to also be an improvement on the costs associated with asset management, resource allocation and the maintenance scheduling strategy.

Operations

If maintenance is done right the first time, then there is no need to submit subsequent work orders for the initial work order to be completed. The principle here is that well maintained components and equipment perform better and ultimately need less frequent service.

The MMIS will facilitate better maintenance and management processes. Regular reports will help identify areas of repeated failure by enabling the maintenance team to identify those components that cost the most to repair or replace.

Asset Management

By being able to keep track of which components the department makes use of, the department is able to eliminate the case of having redundant components and equipment in inventory. This will ultimately reduce capital expenditure and other related inventory costs.

Resource Allocation

The right resources should be available at the right place at the right time. When resources are not available for use in maintenance or, access to components that need maintenance is restricted, a need for a return trip arises. This ultimately results in multiple costs being encountered.

By improving the planning element of maintenance, SAM will be able ensure that there is no need to make unnecessary trips.

Scheduling Strategy

Optimised routes will save travel costs. By making effective use of opportunities (performing a planned service that is almost due on equipment and components when the maintenance team replaces or repairs a component that has broken down on the same asset) the maintenance team is able to reduce the number of needed trips.

11.2. Concluding Statement

Improving the monitoring and control functions contributes to making improvements within the maintenance system. The maintenance manager will thus be able to ensure that work orders are actually completed to satisfaction and on time.

The envisaged benefits to DWA are:

- A simpler way of planning and managing maintenance is achieved.
- Redundant maintenance costs can be eliminated. Thus reducing the overall cost associated with maintenance.
- Better alignment to and achievement of strategic objectives.
- The department is able to better manage operational and maintenance risk.
- Improved control over maintenance will assist in achieving better operational and budgetary efficiencies.
- Improved access to information will assist in making more consistent decisions within the organisation.

The MMIS will decrease the effort associated with monitoring and control of maintenance by facilitating more effective reporting and decision making. This will increase efficiency and improve quality and effectiveness of maintenance within the department.

12. Recommendations

The following recommendations should be considered and steps should be taken to evaluate how effective they will be in making improvements to the maintenance function:

- A maintenance engineer should be involved in the initial design of the asset so that maintenance can form part of the design considerations of the asset.
- The maintenance manager should communicate inspection schedules to the regional and local entity in advance so that access to concealed components on the assets can be created.
- The use of better software packages should be evaluated continuously. National asset management is a large scale project and requires a solution that is capable of handling the demand placed on it.

- The roles of the members of the maintenance team should be clearly defined so as to remove any confusion.
- Inspections should also take into account the use of Root Cause Analysis (RCA) instead of just addressing the issue of resultant failure.
- Management should be fully committed to using the information supplied by the MMIS. This implies that the management style of the section has to be system driven as opposed to just focusing on operations (Coetzee, 1997).

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To my family and The All Mighty, thank you for the support.

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15. Appendices

Appendix A: Project Management documents

- Gantt Chart
- Project Budget

Appendix B: Inspection Sheet Drafts

- 1st Draft Inspection Sheet Template
- 2nd Draft Inspection Sheet Template

Appendix C: Completed Inspection Sheets

Appendix D: Use-case Narratives

Appendix E: Attributed ERD

Appendix F: Map of WMA in South Africa

Appendix A

- Gantt Chart
- Project Budget

ACTIVITIES AND MILESTONES		PROJECT TIMELINE								
	DURATION	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Develop a clear description for the project. This also includes drawing up the project proposal.	39 DAYS	■	■							
Identify the important constraints. Conduct interviews with management.	11 DAYS		■							
Conduct research, put together literature review	82 DAYS		■	■	■	■				
Preparation for presentation, oral exam and typing preliminary project report.	21 DAYS			■	■					
Inspections and Data Collection	123 DAYS				■	■	■	■		
Design of the Information System and validating chosen problem solving method.	122 DAYS					■	■	■	■	
Refine IS versions.	34 DAYS							■	■	
Preparation of concluding statements and recommendations.	63 DAYS							■	■	■
Final presentation of results.	21 DAYS									■

Description	Unit/Monthly price	Quantity	Subtotal
Costs incurred by the department			
Daily Allowance for external work when sleeping overnight	R 85.00	10	R 850.00
Food on Inspections (Average per day)	R 50.00	15	R 750.00
Accommodation (When sleeping overnight)	R 800.00	10	R 8 000.00
Return flights (Average cost from May to September)			
OR Tambo to Bloemfontein	R 2 080.00	1	R 2 080.00
OR Tambo to Cape Town	R 1 793.00	1	R 1 793.00
OR Tambo to Durban	R 1 253.00	1	R 1 253.00
OR Tambo to Port Elizabeth	R 1 694.00	1	R 1 694.00
Costs incurred by the student			
Internet (Per Month)	R 250.00	8	R 2 000.00
Printing	R 0.35	1000	R 350.00
Writing Board	R 300.00	1	R 300.00
Stationery pack	R 200.00	1	R 200.00
Acer Laptop computer	R 6 999.00	1	R 6 999.00
Vodafone HSDPA USB modem	R 1 069.00	1	R 1 069.00
		TOTAL	R 26 269.00

Appendix B

- 1st Draft Inspection Sheet Template
- 2nd Draft Inspection Sheet Template

Date: 05/10/2010
Name: 1st Draft Inspection Sheet

Gate 1:			Gate 2:			Gate 3:			Gate 4:			Gate 5:		
Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	
	Cavitation			Cavitation			Cavitation			Cavitation			Cavitation	
	Corrosion			Corrosion			Corrosion			Corrosion			Corrosion	
	Seal			Seal			Seal			Seal			Seal	
	Cracking			Cracking			Cracking			Cracking			Cracking	
	Structural			Structural			Structural			Structural			Structural	
Other:			Other:			Other:			Other:			Other:		

Comments: ____________________

Emergency Gate 1:			Emergency Gate 2:			Emergency Gate 3:			Emergency Gate 4:			Emergency Gate 5:		
Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	
	Adjustment			Adjustment			Adjustment			Adjustment			Adjustment	
	Cavitation			Cavitation			Cavitation			Cavitation			Cavitation	
	Vibration			Vibration			Vibration			Vibration			Vibration	
	Leakage			Leakage			Leakage			Leakage			Leakage	
	Open/Close			Open/Close			Open/Close			Open/Close			Open/Close	
Other:			Other:			Other:			Other:			Other:		

Comments: ____________________

Butterfly Valve 1:			Butterfly Valve 2:			Butterfly Valve 3:			Butterfly Valve 4:			Butterfly Valve 5:		
Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	
	Seals			Seals			Seals			Seals			Seals	
	Indicators			Indicators			Indicators			Indicators			Indicators	
	Vibration			Vibration			Vibration			Vibration			Vibration	
	Electronics			Electronics			Electronics			Electronics			Electronics	
	Bearings			Bearings			Bearings			Bearings			Bearings	
Other:			Other:			Other:			Other:			Other:		

Comments: ____________________

Sleeve Valve 1:			Sleeve Valve 2:			Sleeve Valve 3:			Sleeve Valve 4:			Sleeve Valve 5:		
Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	
	Motors			Motors			Motors			Motors			Motors	
	Cracking			Cracking			Cracking			Cracking			Cracking	
	Oil Leakage			Oil Leakage			Oil Leakage			Oil Leakage			Oil Leakage	
	Seating			Seating			Seating			Seating			Seating	
	Seals			Seals			Seals			Seals			Seals	
Other:			Other:			Other:			Other:			Other:		

Comments: ____________________

Pipe 1:			Pipe 2:			Pipe 3:			Pipe 4:			Pipe 5:		
Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	
	Cracking			Cracking			Cracking			Cracking			Cracking	
	Leakage			Leakage			Leakage			Leakage			Leakage	
	Corrosion			Corrosion			Corrosion			Corrosion			Corrosion	
	Coupling			Coupling			Coupling			Coupling			Coupling	
Other:			Other:			Other:			Other:			Other:		

Comments: ____________________

Pump 1:			Pump 2:			Pump 3:			Pump 4:			Pump 5:		
Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	
	Electric			Electric			Electric			Electric			Electric	
	Motor			Motor			Motor			Motor			Motor	
	Leakage			Leakage			Leakage			Leakage			Leakage	
Other:			Other:			Other:			Other:			Other:		

Comments: ____________________

Other 1:			Other 2:			Other 3:			Other 4:			Other 5:		
Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	

Comments: ____________________

Inspection Date: 05/10/2010

Asset Name: 2nd Draft Inspection Sheet

water affairs
REPUBLIC OF SOUTH AFRICA

Component Description:	Operational Status:		Working	Not Working
	Condition:			
Age:				
Functionality:	Priority:	1) Max 1 Year	Risk:	1) High
		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Curren:/Pending Activity (Progress):				
Recommendation:				
Required Action (Specific):				

Component Description:	Operational Status:		Working	Not Working
	Condition:			
Age:				
Functionality:	Priority:	1) Max 1 Year	Risk:	1) High
		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Curren:/Pending Activity (Progress):				
Recommendation:				
Required Action (Specific):				

Component Description:	Operational Status:		Working	Not Working
	Condition:			
Age:				
Functionality:	Priority:	1) Max 1 Year	Risk:	1) High
		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Curren:/Pending Activity (Progress):				
Recommendation:				
Required Action (Specific):				

Component Description:	Operational Status:		Working	Not Working
	Condition:			
Age:				
Functionality:	Priority:	1) Max 1 Year	Risk:	1) High
		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Curren:/Pending Activity (Progress):				
Recommendation:				
Required Action (Specific):				

Appendix C

- Completed Inspection Sheets

Table of Contents

Inspection Date: 23/08/2010

Asset Name: Clanwilliam Dam

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Component Description:	Operational Status:		**Working**	Not Working
Knife Gate Valve that is used to isolate Sleeve	Condition:	Piston rod might need lubrication.		
Valve #2.		The Sleeve Valve is isolated.		
		The Gate Valve is in working condition.		
Age: Approx. 8 - 9 years.				
Functionality:	Priority:	1) Max 1 Year	Risk:	1) High
Used to close the outlet pipe and thus isolate the		**2) Max 2 Years**		**2) Moderate**
Sleeve Valve during refurbishment.		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):	N/A			
Recommendations:	The KGV should be tested once a month - ideally.			
Required Action (Specific):	Internal inspection should be performed by local entity later.			

Component Description:	Operational Status:		**Working**	Not Working
Sleeve Valve #2 that controls flow of water from	Condition:	Oil is leaking on both the cylinders.		
the outlet pipe.		There is pitting on the valve stopper.		
Age: Approx. 70 years, with refurbishments.				
Functionality:	Priority:	**1) Max 1 Year**	Risk:	**1) High**
Control flow of water out of outlet pipe #2.		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):	N/A			
Recommendations:	Fix the oil leaks before they become severe.			
Required Action (Specific):	Implement what is recommended.			

Component Description:	Operational Status:		**Working**	Not Working
Sleeve Valve #1 that controls flow of water	Condition:	There is no splash cover over the access hole.		
from the outlet pipe.		There is no stair case leading down to the		
		Spherical Valve that isolates the Sleeve Valve.		
Age: Approx. 70 years, with refurbishments.		The Sleeve Valve is in good working condition.		
Functionality:	Priority:	**1) Max 1 Year**	Risk:	**1) High**
Control flow of water out of outlet pipe #1.		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):	N/A			
Recommendations:	For safety reasons, the stair case and cover are needed.			
Required Action (Specific):	Implement what is recommended.			

Component Description:	Operational Status:		**Working**	Not Working
Valve control panel with electronic switches.	Condition:	Working properly.		
		All the phases are operational.		
		Valves are operated with ease.		
Age: Approx. 5 years.		Limited access to fuse box restricts maintenance		
Functionality:	Priority:	**1) Max 1 Year**	Risk:	**1) High**
Used to operate the hydraulically actuated Sleeve		2) Max 2 Years		2) Moderate
and Knife Gate valves.		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):	N/A			
Recommendations:	Operate periodically and service electronic components.			
Required Action (Specific):	Move a pipe that is restricting access to the fuse box!!			

Inspection Date: 25/08/2010

Asset Name: Oukloof Dam

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Component Description:	Operational Status:		Working	Not Working
Left Wedge Gate (#2).	Condition:	Leakage on the valve casing.		
		Shaft has been disconnected from the blade		
		due to the thread been stripped off.		
Age:				
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
Used to release water into the canal.		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):	N/A			
Recommendations:	Investigate alternative design. Perform FMEA and RCA.			
Required Action (Specific):	Repair or Replace the Wedge Gate.			

Component Description:	Operational Status:		Working	Not Working
Sleuce Gate turning wheel casing.	Condition:	Bolts are rusted.		
		Some of the bolts are missing.		
Age:				
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
Houses the gear mechanism for the turning wheel.		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):	N/A			
Recommendations:	Replace with galvanised bolts.			
Required Action (Specific):	Implement what is recommended.			

Component Description:	Operational Status:		Working	Not Working
	Condition:			
Age:				
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):				
Recommendations:				
Required Action (Specific):				

Component Description:	Operational Status:		Working	Not Working
	Condition:			
Age:				
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):				
Recommendations:				
Required Action (Specific):				

Inspection Date: 24/08/2010

Asset Name: Poortjieskloof Dam

Department: Water Affairs
REPUBLIC OF SOUTH AFRICA

Component Description:	Operational Status:		Working	Not Working
Sleuce Gate to the outlet pipe.	Condition:	Rusted hinges on the access gate.		
		Gate Valve actuating wheel is rusting.		
		Outlet pipes are corroding.		
Age:		The gate is leaking.		
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
Controls flow out of the outlet pipe.		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):	N/A			
Recommendations:	Investigate the use of alternative non-corroding components.			
Required Action (Specific):	Stop the leakage on the gate as soon as possible.			

Component Description:	Operational Status:		Working	Not Working
Wedge Gate Valve on the outlet pipe.	Condition:	The wheel is corroding.		
		Nuts and bolts are also corroding.		
		The indicator is still working.		
Age:				
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
Controls flow out of the outlet pipe.		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):	N/A			
Recommendations:	Replace the bolts with galvanised ones.			
Required Action (Specific):	Implement what is recommended.			

Component Description:	Operational Status:		Working	Not Working
Stair case and guard rail on the down stream side	Condition:	The back support is rusting.		
of the dam wall.		Nuts are missing on the base of the guard rail.		
Age:				
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
Provides access to pipes and actuating wheel on		2) Max 2 Years		2) Moderate
the down stream.		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):	N/A			
Recommendations:	Treat the corrosion or replace the stair case.			
Required Action (Specific):	Replace missing bolts with galvanised ones.			

Component Description:	Operational Status:		Working	Not Working
	Condition:			
Age:				
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):				
Recommendations:				
Required Action (Specific):				

Inspection Date: 24/08/2010

Asset Name: Roode Elsberg Dam

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Component Description:	Operational Status:		Working	Not Working
Sleeve Valve control wheel.	Condition:	Working properly, but with considerable level		
		of difficulty.		
Age: Approx. 40 years, with refurbishment.				
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
Used to manually actuate the Sleeve Valve during		2) Max 2 Years		2) Moderate
operation.		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):	N/A			
Recommendations:	Replace with a hydraulic system.			
Required Action (Specific):	Implement what is recommended.			

Component Description:	Operational Status:		Working	Not Working
Sleeve Valve.	Condition:	The old design is no longer efficient.		
Age: Approx. 40 years, with refurbishment.				
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
Control flow from the outlet pipe.		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):	N/A			
Recommendations:	Investigate new design technology and best practice.			
Required Action (Specific):	Replace the old design with a new researched design.			

Component Description:	Operational Status:		Working	Not Working
	Condition:			
Age:				
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):				
Recommendations:				
Required Action (Specific):				

Component Description:	Operational Status:		Working	Not Working
	Condition:			
Age:				
Functionalty:	Priority:	1) Max 1 Year	Risk:	1) High
		2) Max 2 Years		2) Moderate
		3) Max 5 Years		3) Low
Current/Pending Activity (Progress):				
Recommendations:				
Required Action (Specific):				

Inspection Date: 25/08/2010

Asset Name: Roodefontein Dam

water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA

Component Description:	Operational Status:		Working	Not Working
Sleeve Valve.	Condition:	Corroded on the inside.		
		Grease nipples are corroded		
Age: Approx. 20 years				
Functionality:	Priority:	1| Max 1 Year	Risk:	1| High
Used to release water into the outlet pipe.		2| Max 2 Years		2| Moderate
		3| Max 5 Years		3| Low
Current/Pending Activity (Progress):	N/A			
Recommendation:	Treat the corrosion and replace the grease nipples.			
Required Action (Specific):	Impement what is recommended.			

Component Description:	Operational Status:		Working	Not Working
Gate Valve #1.	Condition:	The valve is not being properly sealed.		
Age: Approx. 20 years				
Functionality:	Priority:	1| Max 1 Year	Risk:	1| High
Isolates the Sleeve Valve when maintenance has to		2| Max 2 Years		2| Moderate
be performed.		3| Max 5 Years		3| Low
Current/Pending Activity (Progress):	Previous recommedations are still pending.			
Recommendation:	Repair the seal immediately.			
Required Action (Specific):	Impement what is recommended.			

Component Description:	Operational Status:		Working	Not Working
Upstream inlet pipe.	Condition:	Paint is flacking.		
		The thread on the sacrificial anode s corroding		
		and worn off.		
Age: Approx. 20 years				
Functionality:	Priority:	1| Max 1 Year	Risk:	1| High
Used for flow of water out of the dam to the outlet		2| Max 2 Years		2| Moderate
works.		3| Max 5 Years		3| Low
Current/Pending Activity (Progress):	N/A			
Recommendation:	Repaint the exterior and replace the sacrificial anode.			
Required Action (Specific):	Impement what is recommended.			

Component Description:	Operational Status:		Working	Not Working
	Condition:			
Age:				
Functionality:	Priority:	1| Max 1 Year	Risk:	1| High
		2| Max 2 Years		2| Moderate
		3| Max 5 Years		3| Low
Current/Pending Activity (Progress):				
Recommendation:				
Required Action (Specific):				

Appendix D

- Use-case narratives

Table of Contents

List of Acronyms

ERA	External Receiver Actor
ESA	External System Actor
PBA	Primary Business Actor
PSA	Primary System Actor

1. Asset Management Subsystem

Use-case name:	Create component record
Primary Business Actor:	Maintenance Manager
Additional Actors:	Additional System User (PSA)
Other interested Stakeholders:	Strategic Asset Management directorate
Description:	The user creates the records of the critical components on the different assets. This is the first step taken to populate the database so that it can be used to serve the requirements (and objectives) of the system.

Use-case name:	Manage components
Primary Business Actor:	Maintenance Manager
Additional Actors:	Additional System User (PSA)
Other interested Stakeholders:	Strategic Asset Management directorate
Description:	Read, update and delete the records of the components that are found in the database.

2. Maintenance Subsystem

Use-case name:	Manage maintenance tasks
Primary Business Actor:	Maintenance Manager
Additional Actors:	N/A
Other interested Stakeholders:	N/A
Description:	Record the specific tasks that need to be performed on a component that is found on an asset. The Use-case also describes who is responsible for assigning an entity (contactor/section)to maintenance.

Use-case name:	**Manage maintenance schedule**
Primary Business Actor:	Maintenance Manager
Additional Actors:	N/A
Other interested Stakeholders:	The regional entity that oversees operations has to be informed of the schedule.
Description:	Mange the sequence of maintenance activity.

Use-case name:	**Manage maintenance progress status**
Primary Business Actor:	Maintenance Manager
Additional Actors:	Strategic Asset Management directorate (ERA)
Other interested Stakeholders:	The longer maintenance takes, the more costly it is and the more risk accumulates. DWA and S.A. public will be affected by the status.
Description:	Manage the progress status of maintenance that is either pending or complete.

Use-case name:	**Maintenance report**
Primary Business Actor:	Maintenance Manager
Additional Actors:	Time (PSA), Strategic Asset Management (ERA)
Other interested Stakeholders:	The regional entity should be made aware of how well they are performing. The report should be comprehensive and understandable.
Description:	This Use-case produces the maintenance monthly report. The Use-case is triggered by time.

3. Inspection Subsystem

Use-case name:	Manage component condition
Primary Business Actor:	Maintenance Manager
Additional Actors:	N/A
Other interested Stakeholders:	Strategic Asset Management directorate, S.A. public, DWA.
Description:	Update the component's condition.

Use-case name:	Manage inspection schedule
Primary Business Actor:	Maintenance Manager
Additional Actors:	N/A
Other interested Stakeholders:	The regional entity that oversees operations has to be informed of the schedule.
Description:	Manage the sequence of inspections.

Appendix E

- Data Entity Dictionary
- Attributed ERD

Table of Contents

1. Data Entity/Table Dictionary

1.1. Asset

The asset table represents a dam, canal, pumping station or pipeline and not a specific piece of equipment or component. The equipment and components that will be evaluated form part of the assets that are referred to in this report.

1.2. Component

This table represents the information about a component that is captured onto the database. For the sake of this project, only components that are thought to be critical to the function of the asset as a whole will be considered.

1.3. Component per asset

A number of components are found on an asset. Information related to the critical components on each asset that will be inspected and maintained will be captured onto the database.
This associative table will be used to create a normalized relationship between the component and asset tables. This type of table is used to replace the unwanted *"many to many"* relationship.

1.4. Condition

The condition table has attributes that will influence how records of equipment/component condition are created. Risk profiles and the assigned priority are attributes of the component's condition.

1.5. Entity

The table named entity represents an individual or group that will be assigned maintenance work orders.

1.6. Inspection

The inspection table represents the attributes of an inspection that will be carried out on an asset. The inspection is a known certainty and is an element of the entire process that will be present.

1.7. Maintenance

The maintenance table represents a generic term that includes planned/unplanned maintenance, repair, refurbishment and renewal. The provision for the replacement of infrastructure has also been included in this definition.

1.8. Maintenance per asset

Each asset will have a specific type of maintenance that is carried out. This table is an associative table and it is used to create a normalized relationship between the maintenance and asset tables. This type of table is used to replace the unwanted *"many to many"* relationship.

1.9. Maintenance per component

Each component fails and functions in a unique manner and will thus have a specific type of maintenance that is carried out. This table is an associative table and it is used to create a normalized relationship between the maintenance and component tables. This type of table is used to replace the unwanted *"many to many"* relationship.

1.10. Operational status

This table will be used to store data that will ultimately enable the maintenance manager to know whether any of the components the organisation is interested are working or not.

1.11. Recommendation

This table represents the recommendations that will follow each inspection that is carried out.

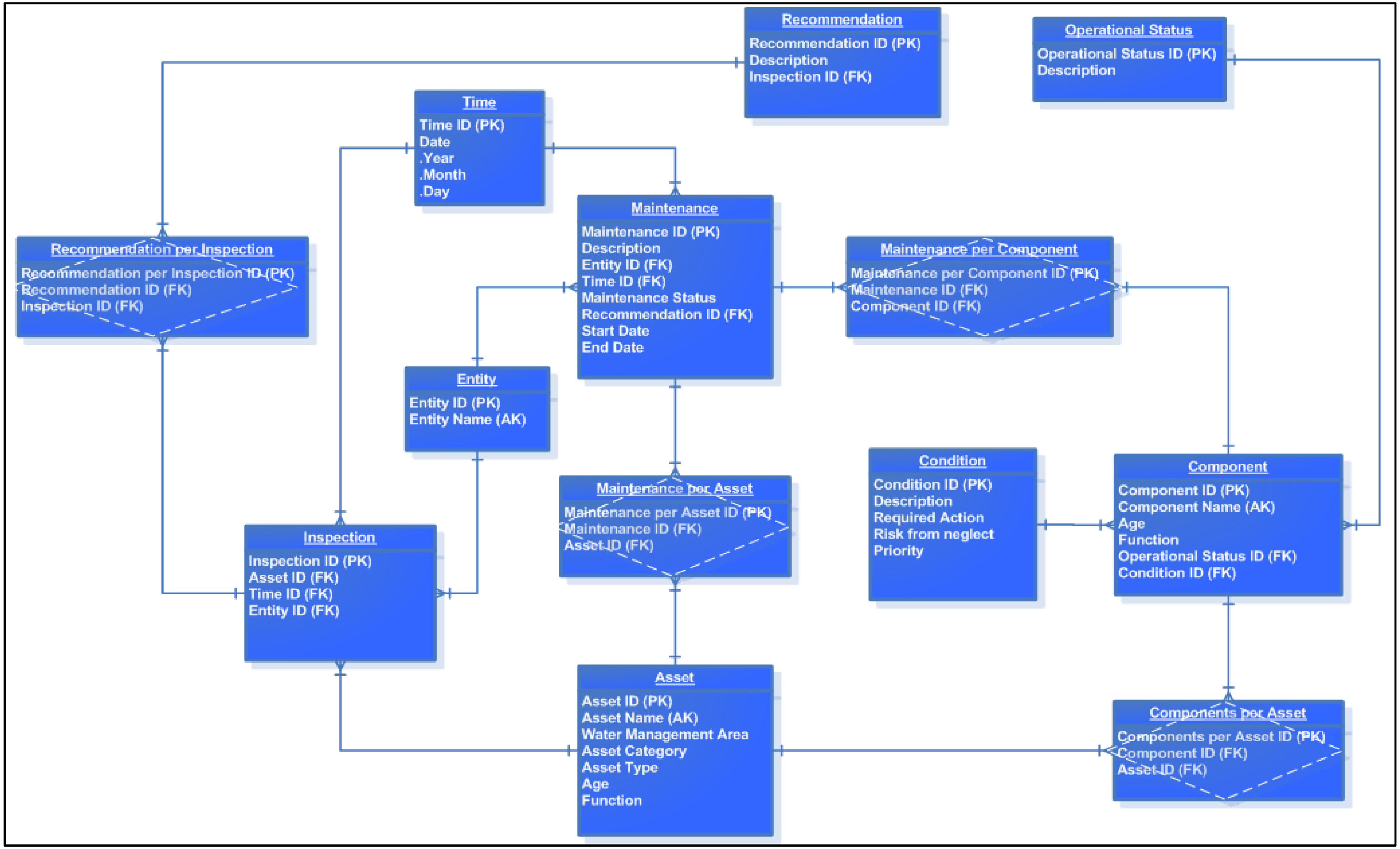
1.12. Recommendation per asset

Each asset will have a specific set of recommendations that is unique. These recommendations will be made as a result of what is discovered during an inspection. This table is an associative table and it is used to create a normalized relationship between the recommendations and asset tables. This type of table is used to replace the unwanted *“many to many”* relationship.

1.13. Time

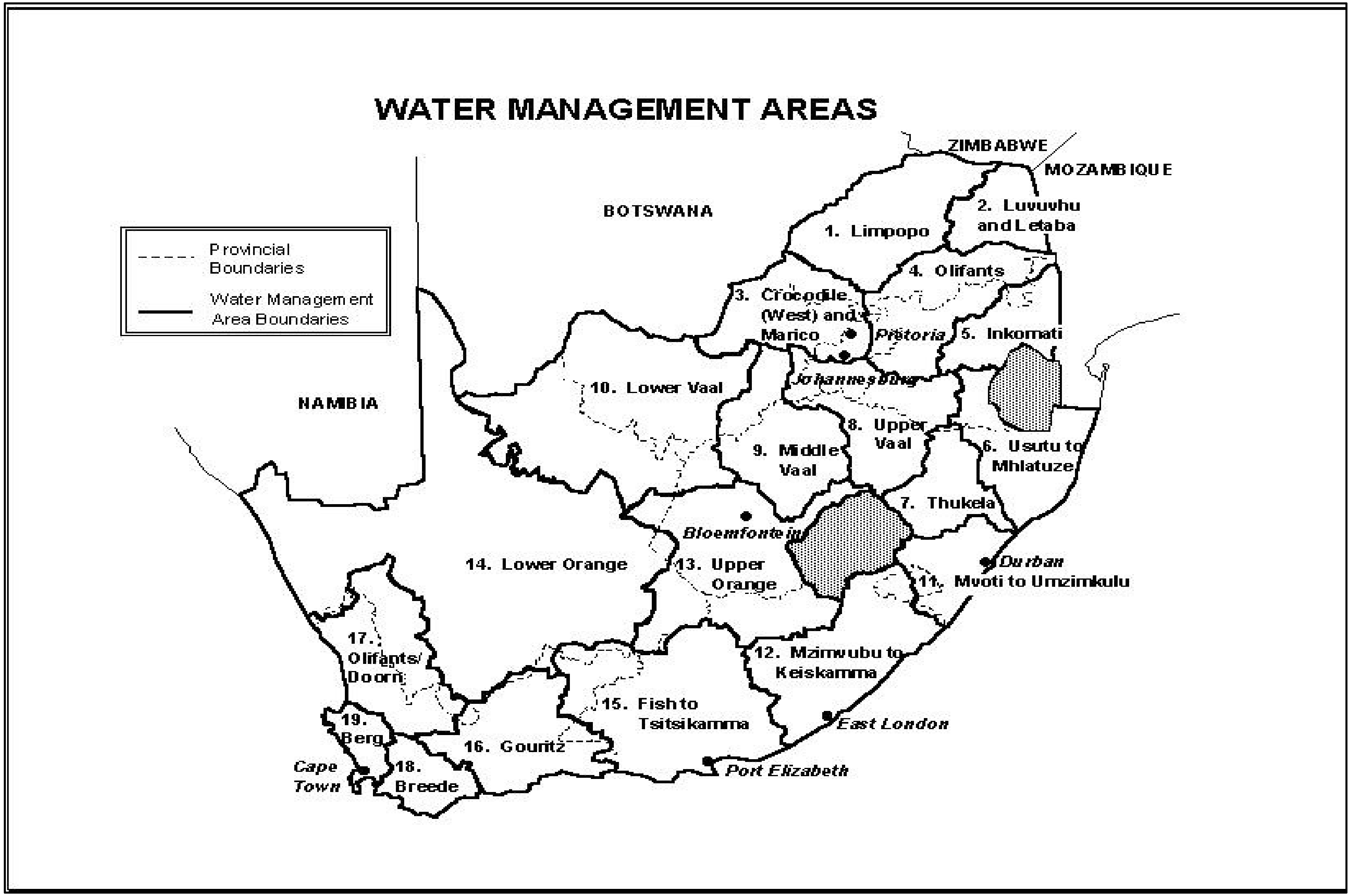
The entire maintenance process is dependent on time as a constraint and as a guide. The maintenance schedule will dictate when maintenance is carried out and when reports should be released for evaluation of the maintenance work orders.

2. Entity Relationship Diagram



Appendix F

- Map of WMA in South Africa


WATER MANAGEMENT AREAS
ZIMBABWE
MOZAMBIQUE
BOTSWANA
NAMIBIA
Provincial Boundaries
Water Management Area Boundaries
1. Limpopo
2. Luvuvhu and Letaba
3. Crocodile (West) and Marico
4. Olifants
5. Inkomati
6. Usutu to Mhlatuze
7. Thukela
8. Upper Vaal
9. Middle Vaal
10. Lower Vaal
11. Mvoti to Umzimkulu
12. Mzimvubu to Keiskamma
13. Upper Orange
14. Lower Orange
15. Fish to Tsitsikamma
16. Gouritz
17. Olifants/ Doorn
18. Breede
19. Berg
Pretoria
Johannesburg
Bloemfontein
Durban
East London
Port Elizabeth
Cape Town