resource that the community uses, water quality problems they have observed and how they feel about the amount of water they their neighboring developer is applying for. The function of conducting public participation should be assigned within the relevant sub-directorate in DWS. Currently this function is carried out by the clients themselves and that opens a loophole on an issue of handling public participation.

7.2.4 WUAAAC decision

WUAAAC is a committee that is established from DWS and it is given a mandate to take decisions when any of the water uses is authorized. For groundwater abstraction water used authorization the qualified geohydrologist should be part of the committee to help with the review of geohydrology report from the client or client's consultant. The geohydrologist should look at issues such as the capacity of the borehole, water quality and if the content of a report was covered correctly including borehole siting, borehole drilling and geological logging, identification of the main water strike and if the available drawdown was determined correctly. The positioning of the pump and its capacity is also important to look at together with the pumping cycle if it was determined correctly. Lastly the geohydrologist should advice the committee for which parameters should the client monitor and for how long should the client be authorized to pump water from the borehole.

7.3 Conclusion

From this investigation it is concluded that the three main objectives were responded to and the main aim of the investigation was addressed. The local approach to make an informed decision when issuing the groundwater abstraction water use licence was addressed. However, there are hypothesis that were not responded to such as the one of GW-SW interaction.

7.4 Decision making on the current study

Figure 7.1 shows the components of the current geohydrological study and how the decision was made. The diagram outlines the objectives of the study which are 1) Determine hydraulic properties of the aquifer at the local scale in the case study area, 2) assess groundwater and surface water quality for irrigation in the case study area, 3) evaluate groundwater contribution to surface water in the case study area. It further gives the methods that enabled the current study to respond to the objectives and those were 1) analysis of geochemistry and surface water chemistry, 2) conducting a pumping test, and 3) comparing surface water with groundwater do determine the interaction. The diagram also outlines the results and recommendations from the geohydrological report.

7.5 Recommendation

For groundwater management purpose on site, it is recommended that production boreholes be pumped at a recommended rate of 1.02 l/s in BH03 and BH05 which is equivalent to 32188.06 m^3/a, the pump should be installed at a depth of 135 mbgl for both BH03 and BH05 based on the water strikes determined by Lasher, 2011, the continuous monitoring of water quality once in six months should be carried out, the continuous monitoring of water levels from all the boreholes in the surrounding takes place at least once a month or the installation of water level loggers to all the monitoring wells or nearby well from the pumped wells, and the continuous monitoring of stream discharge using current meter takes place at least once in six months or a proper weir should be installed. The records for data collected from site should safely be kept by a client for in case the Department of Water and Sanitation (DWS) requests the data. The chemical analysis using piper diagram and using stream flow measurements suggested that BH03 and BH05 are connected hydraulically. The recommendation for a licence condition is to investigate further if there is connection between groundwater and surface water in the local area and how the groundwater abstraction will affect the surface water resource in the surrounding area.

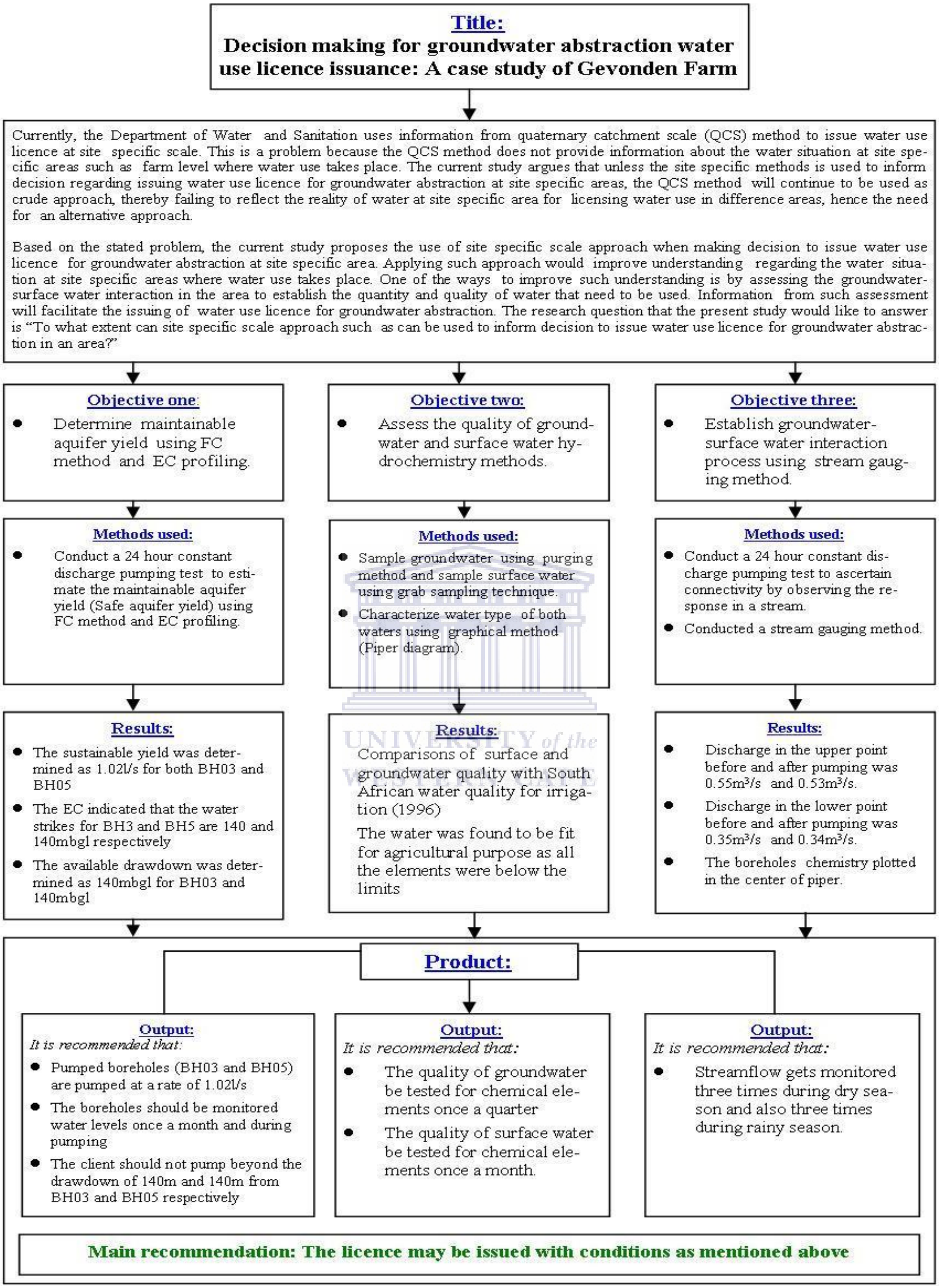

Figure 7-1: The diagram outlines the conduction of the study until decision making

7.6 Adaptive management

The process used to take a decision for the issuance of groundwater abstraction water use licence leaves behind a number of questions unanswered. Those questions are; can the water use licence be confidently issued based on the recommendations of a Reserve? Can we not issue the groundwater abstraction water use licence because the Reserve indicates the deficit in groundwater resource within a particular quaternary catchment? If the Reserve indicates that there is enough water, is the Department sure of the calculation used to determine the available water? Can a decision to issue be supported with only the site specific geohydrological report prepared by a client? The questions trigger the suggested adaptive groundwater management.

The adaptive management is generally explained as learning from implementation (Allan, 2007). There are four fundamental steps to understand in adaptive management and those are 1) Planning, 2) implementation, 3) Monitor and, 4) learning. There three types of adaptive management and those are 1) Evolutionary, 2) Passive and, 3) Active adaptive management. Evolutionary adaptive management is undirected learning from random experience, or trial and error learning. Passive adaptive management has a strong focus on implementation, in particular the implementation of a historically informed best practice or policy, followed by review of that implementation. Active adaptive management, like passive adaptive management, is about implementation, but there is a stronger emphasis on learning.

The adaptive management suggested in the current study is active adaptive management as it emphasizes more on learning. However active adaptive management does not mean all the water use applications for groundwater abstraction need to be issued and after that get closely managed. There should still be a criteria used to evaluate the water use licence application for groundwater abstraction. The suggested steps to appear in the criteria are 1) geohydrological report that responds to the potential of the borehole to give the amount of water applied for, 2) fitness of water quality for agricultural or human consumption depending on what are was an application about and 3) If the there is a surface water resource or even groundwater resource situated nearby there should be a study conducted to evaluate the interaction between these resources.

However, the first steps of the criteria to be followed are 1) is the borehole 100m away from any water resource? 2) Was the public participation conducted to ensure that the neighbors do not object the groundwater abstraction applied for? And 3) is the borehole not next to any source of pollution that might cause threat to groundwater quality? The issues that make the Reserve to be unable to stand litigation should be addressed because either than that the use of Reserve for decision making becomes irrelevant if the client appeal the decision of not issuing the licence because deficit realized from the catchment.

In a case of the current situation created in the case study area of Gevonden Farm with relation to adaptive management the following condition need to be specified to a client, 1) The water meter should be installed to measure the amount of water abstracted per day, 2) The groundwater levels should be measured from the borehole pumped borehole and monitoring boreholes once a month, 3) The water quality samples should be obtained from the river and five boreholes on site and sent to the accredited laboratory for analysis seasonally, 4) All records for the information collected should be stored safely for in case DWS request to have them.

7.7 Capture principle

Other studies have suggested that capture method (Alley et al., 1999 and Seward et al., 2006) is a method that can be used to determine sustainable yield within a quaternary catchment to substantiate decision making when the groundwater abstraction water use licence is issued. Capture is defined as the sum of the increase in recharge and decrease in discharge (Lohman, 1972). For the current study capture principle is not an alternative as it still does not consider the parameters to be considered at local scale for the licence issuance.

7.8 Groundwater resource assessment at local scale

The assessment of a production borehole requires the preparation of geohydrology report that entails the sitting, drilling, pump testing and water quality testing. Information that needs to be depicted in each and every section of this nature of a geohydrological report has not been dealt with in details to make an informed decision during the licence processing. The main suggestion going forward is that this nature of a report should serve a training to capacitate young geohydrologist so that they can understand what they are doing during geohydrological report review.

Further suggestions are that GW-SW interaction investigation needs suitable borehole construction. Understanding of the types of aquifers that exist in the area is important. The categorization of aquifer into primary and secondary aquifer is required. In the case study area the shallow aquifer is regolith or primary aquifer and the deep aquifer is hard fractured rock or secondary aquifer. The construction of a shallow borehole was supposed to be such that it allows recharge from the shallow aquifer only. The borehole should be capped at the bottom so that it does not allow water from the deep aquifer to vertically get into the shallow borehole.

The borehole representing the deep aquifer should also be constructed such that it allows no water from the shallow aquifer to get to the deep aquifer. This can be achieved by using two different drilling rigs diameters normally through the shallow regolith aquifer the 203mm diameter should be used and from the hard rock or deep aquifer the 165mm diameter should be used. In the 203mm drilling rig diameter (shallow aquifer), the plain steel or PVC casing larger than the pipe to go through the deep aquifer. The small diameter pipe going through the deep aquifer should be perforated to the depth where water strikes were identified. The bottom of the shallow aquifer in the deep aquifer should be sealed with bentonite seal in the laminar space between the steel and PVC casing. Such shallow and deep boreholes construction will render the two different waters from two different aquifers.

7.8.1 Borehole purging before sampling

Purging of each borehole before taking some field measurements and samples is important. The recommended method of purging is the calculation of a column of water in the borehole and purge three times the calculated volume Weaver et al., 2007. The prescription of a pump size that will pump water required from a borehole is prescribed by conducting a step test. In the current study the step test was not conducted due to financial constrains. Geological logging for the development of a conceptual model of an aquifer was not done and geophysics for borehole siting was not carried out before borehole drilling. The three components of the study are important as they contribute to management recommendations for sustainable use of a borehole. It is therefore suggested that step test, geological logging and geophysics are included in the next study.

There are some field measurements that could be obtained for stream-aquifer interaction, but may give misleading results due to incorrect assumptions. The first one is inaccurate gauging survey. It is conceptually appealing to assess stream depletion effects by simply pumping a well for a period of time and monitoring the flow in a nearby stream to see the change that occurs. Float methods and current meters can be used to measure the water flow rate and when this information is combined with the cross-sectional area of the flow channel, the flow rate can be estimated. However, this is not a reliable method of assessment due to measurement inaccuracies coupled with background fluctuations in stream flow compared to the relatively small effect from a pumping well, particularly over short pumping periods (i.e. less than 48 hours).

Water chemistry analyses: consideration may also be given to measuring the change in water quality characteristics that occurs between the surface water body and the groundwater. If such a parameter could be found then monitoring of the water quality in the pumped well could detect a change in the proportion of surface water being pumped from the well. For instance, a common example of the change in water chemistry between surface water and groundwater occurs in the pH value of the water.

One difficulty that exists with such chemical indicators of surface water is that many of the chemical parameters will typically undergo chemical transformation as they move through the streambed and into the subsurface environment. Consequently, by the time any water that originated from the surface water body reaches a well, its chemical composition will have been modified so that it can no longer be directly compared with the chemical composition of surface water.

Stream depletion effects can occur without any stream water reaching the well. The stream depletion effect is caused by a pumping well creating a change in hydraulic gradient adjacent to the streambed which results in a loss in streamflow, or an equivalent reduction in groundwater seepage that would otherwise enter the stream. This effect can occur without any surface water actually was drawn into the well. As a result, sampling the water quality of the pumping well for surface water indicators cannot be used as a reliable measure of stream depletion effects.

Pumping test results near streams: pumping test is a common hydrogeological field technique to determine aquifer transmissivity and storage characteristics. They involve the pumping of an individual well at a constant rate for a period of several hours whilst the drawdown in water levels is measured both in the pumped well and in surrounding “observation wells. These tests are typically analysed using methods that assume the aquifer is of infinite extent. However, if such tests have taken place in aquifers where stream depletion effects are expected to occur then it may be inappropriate to use aquifer parameters that have been analysed using the assumption of an infinite aquifer. In such circumstances it will be more appropriate to re-analyse the test data using the approach described in Hunt (1999). It has also sometimes been misleadingly reported that because pumping tests have created very small drawdowns, there must be no stream depletion effect occurring. However, it is often the recharge from a stream that causes the small drawdown effects during pumping.

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