Queensland University of Technology

School of Mathematical Sciences

MXB324: Computational Fluid Dynamics

Project Management Update

Group 007

Bond Consulting

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Contents

1 Foreword

The following report is an updated version of the original Project Management Deliverables submitted in the Progress Report. The changes in this updated report have been made to reflect the changes made in the lifecylce of the project.

The updates made in this report have been coloured blue for ease of identification. Changes have been made in the following sections:

- Project Objectives
- Broad Project Approach
- Project Descriptions
- Product, Work and Operations Structure
- Organisational Structure
- RACI Diagram
- Schedule
- Lessons Learned

2 Introduction

Water is a vital component of everyday life. From agricultural needs, industrial use and most importantly domestic consumption, fresh water plays a pivotal part in everyday life. The most accessible form of fresh water is found on the surface of the Earth. Streams, lakes, rivers and dams are all examples of this water resource. However, surface water is only 0.1% of all water on Earth and its accessibility is highly dependent on geographical location and infrastructure to transport the water. Groundwater, on the other hand, is water that resides underneath the Earth. It comprises of approximately 2% of all fresh water on Earth (2000 times more than surface water), forming vast underground oceans and lakes of which are easily accessible via bores or wells.

As the worlds populations increase and communities become larger and larger, the demand for accessible, fresh water is ever increasing. Around the world, groundwater is already a necessary resource for many countries, with at least 50% of the worlds population dependent on underground aquifers [1]. A similar dependency is seen across Australia with a large percentage of rural towns already relying solely from groundwater. In conjugation with an increasing dependency, groundwater is also subjected to a slow replenishment rate.

Due to the natural creation of underground aquifers forming over hundreds of years, the replenishment rates of groundwater are very slow. Because of these characteristically slow recharges, it is vital to be able to accurately model the flow of groundwater and understand the influence external factors have on the stability of the groundwater system. By doing so, the underground aquifers are able to be effectively managed and accommodate future dependencies on this precious resource. This particular concern of groundwater management is what will be investigated in the project being undertaken.

The following report will propose an outline of how the project team plans to conduct the development of a groundwater simulation software and an analysis report of the results of the simulation. The project objectives will be identified and a detailed breakdown of the project will be approached along with a breakdown of the products to be produced. A description of these products will provide detail into how these products will be utilised, the assumptions, exclusions and constraints applied in the development of the project will be addressed, the stakeholders involved and their expectations surrounding the project will be identified and an analysis of the risks and issues involved with the project will be conducted.

3 Justification of Project

The project is being undertaken to assess the impact a newly proposed Coal Seam Gas (CSG) plant will have on the local water aquifer. The local water aquifer is an important water resource for the nearby environment, with the extracted water enabling irrigation of crops, maintenance of the health of the surrounding forests/ecosystems, a water resource for the local town as well as industrial use. Construction of the CSG plant and subsequent extraction of groundwater may have critical impacts on the health of the aquifer, which in turn will affect the local area and community. Hence, it is highly important to be able to model the impact the aquifer system in order to identify possible consequences of the introduction of the CSG plant.

The aquifer is also highly dependent on the local weather, with drought, evapotranspiration, flooding and rainfall all having an influence on the health of the aquifer. Thus, a rainfall model will be developed to determine the short and long term predicted rainfall. This rainfall model will be based on the rainfall data collected from the local area between 1940-2018.

There is a large community benefit in the construction of the CSG in terms of job creation and economical growth. Hence, it is highly important to be able to develop an accurate simulation model of the groundwater system in order to determine the influence the CSG plant will have to the stability of the aquifer. From conducting an analysis on the groundwater system, mitigation techniques can be suggested to minimise/avoid potential impacts/issues of the CSG if deemed necessary.

4 Project Scope

The proposed groundwater model will be utilised to simulate changes in the local river flow and aquifer subjected to specific external variables (town water supply, CSG plant, irrigation, etc). The main outcome of this project will be the ability to identify the change of the groundwater flow/health of the local aquifer from multiple variables over a significant time frame. Depending on the impact these variables have on the aquifer, mitigation techniques can be tested via the model simulation and the techniques effectiveness can be determined.

The primary product that will be created is the groundwater simulation software. However, numerous other products will be required to be produced in order to achieve this goal. A model of the predicted future rainfall will be created to assist in determining the volume of water entering the system from above ground level. Multiple MATLAB scripts will also be written in order to model the physical phenomenon present in the groundwater system (i.e. soil saturation, pressure head, evapotranspiration, etc.) as well as the intrinsic properties of the differing soil layers.

The work to be undertaken will include the initial construction of a mathematical model that implements the appropriate physical characteristics dictated by the region of interest, the creation MATLAB scripts based on the aforementioned mathematical model and the formation of a rainfall model to predict future rainfall in the area.

5 Assumptions, Exclusions, Constraints

5.1 Assumptions

In order to effectively simulate the flow of groundwater, multiple assumptions are necessary to simplify the model. The first of these assumptions arise in assuming that a two dimensional model is appropriate in modelling a three dimensional system. Without this assumption, the simulation becomes exponentially more difficult to model both mathematically and computational due to the increase in variables.

It is also necessary for other assumptions to be implemented in order to maintain the appropriateness of the two dimensional model. Firstly, the region being modelled is required to be large and that there is negligible effects in the y-direction (i.e. water flow only in the x and z directions). Secondly, The aquifer depth is constant throughout the simulation and that the intrinsic soil parameters are homogeneous within each layer irrespective of depth. Lastly, it is important for the permeability of water is higher in the horizontal direction compared to the vertical direction. This encourages water flow in the horizontal plane and minimises unrealistic flow upwards (i.e. against gravity).

Further assumptions are then made to the specific parameters and events to removed ambiguity and create a more idealistic model. These assumptions include assuming that the town water consumption and evapotranspiration rates are constant, that the evapotranspiration regions do not change, that the soil regions are static (i.e. no changes to soil layers via movement of earth/earthquakes) and that there are no drastic weather events that would greatly disturb the local region (e.g. flooding, extended drought, cyclones). It is also assumed that the aquifer is confined in position (i.e. does not change during the simulation) and that the recharge of the aquifer is dependent only on water flow from the river or from rainfall. All these assumptions provide necessary clarity and enable simplification of a complex, multivariable system to be modelled.

Additional assumptions of the constructed rainfall model are also implemented such as that the predicted rainfall model accurately represents real world rainfall and that the rain falls homogeneously across the region of interest.

5.2 Exclusions

Along with assumptions, there are also certain issues that the model simulation will not attempt. The primary exclusion is that the model does not evolve in time. This means that it is expected that there is no change to boundary conditions, soil parameters or layer regions within the soil throughout the lifetime of the simulation.

Another exclusion is the fact that the software that will be developed from the project is only a prototype. Further improvement on user interfaces would be required in order to mass distribute this software. The reason for this exclusion is due to the limited access to company personnel to identify their user needs and requirements for the software.

5.3 Constraints

There are a number of constraints placed upon the capability of the groundwater simulation software due to either the simulation model itself or external factors impacting the production of the software. In regards to the software, the model used to simulated the groundwater flow within the specified region of interest was built upon an idealised framework. Soil parameters, differing soil layers, ecological (i.e. agriculture, rainforests) and domestic regions (town) as well as physical phenomenon assumptions (e.g. water flow being more prevalent horizontally than vertically) will all be utilised in order to simplify the physics/mathematics of the system. Additionally, the region of interest is constrained to a two dimensional framework instead of a three dimensional framework in order to further reduce the total variability within the modelled system.

By performing these simplifications, the original, three dimensional and highly complex region of interest being investigated can be systematically broken down into a more manageable, less complex, two dimensional system that still retains the major physical phenomenon present in the original. This idealisation of the model ultimately leads to a less accurate simulation compared to that of three dimensional model that allows for more variation within measured parameters. However, the non-idealised model would require an exceptionally greater cost in terms of computational power, time availability, capability of team members, measurement of data and predicted future forecasts on town population and agricultural development.

There are also a few external factors that will limit the capability of the software product. These factors include availability of stakeholders, time period given for the completion of the software product, availability of team members as well as capability of team members. With limited availability with stakeholders, there may be slight misinterpretation of the specifications required of the software prototype. The production of the software is also limited by the time frame given to complete the construction of the product. Finally, the group members are also restricted by other time obligations (other subjects, work, etc.) as well as inexperience in creating a groundwater simulation model.

6 Project Objectives

The objective of the project is to construct a groundwater simulation software to model the groundwater flow within the Canning Downs region and to present an analysis report on the results of the groundwater simulations. To do this, multiple MATLAB scripts will be developed to replicate the physics and intrinsic qualities pertaining to the groundwater system and a complex rainfall model will be developed to predicted future rainfall within the area.

Verification procedures will be implemented to ensure that simulation software accurately reflects real world phenomenon. These procedures will include comparing the appropriateness of the physics simulated in the software to the real world (i.e. soil saturation is expected to be greater closer to water bodies) and ensuring that the rainfall model accommodates for wet/dry seasons and that the yearly average rainfall is consistent with previous years.

The deadline for the analysis report is 1st November, 2019 with a presentation to the project board occurring on the 28th October, 2019. The presentation will provide a forum to discuss the results obtained from simulations of the groundwater system, the key findings identified during the analysis of the results and highlighting any recommendations/mediation strategies required in the construction of a CSG plant. Prior to these key milestones, the code from which the simulation is performed will be developed and verification methods will be conducted to validate the output results of the code.

7 Broad Project Approach

Due to the nature of the projects life-cycle, it is fitting to utilise an agile approach to completing the majority of the project tasks. This is because the information/knowledge required in completing many of the tasks of the project will be delivered in a weekly manner. For example, in order to fully understand how to mathematically breakdown the Canning Downs region of interest, the Project Sponsor (Ian Turner) stepped the project group through the process over a 5 week period. This style of delivery on specifications and scope of the project is hence most suited to an agile approach.

In regards to the construction of the products that will be produced, this agile approach will be more beneficial in being able to trouble shoot issues and better adapt any of the products to industry expectations. The project group intends to build MATLAB scripts to model the physical and intrinsic phenomenon present within the system. These scripts will be continuously tested during the development of the code to verify that the scripts work as intended. A similar approach will be used when constructing the predicted rainfall model, with each iteration of the modelling being tested and improvements implemented in the next model iteration.

Finally, an agile approach will also be used in developing the groundwater simulation software prototype. The software prototype will incorporate the MATLAB scripts developed with the predicted rainfall model. Thus, by utilising an agile approach, the group will be able to trouble shoot any issues/identify any improvements within the software more efficiently.

To validate the work being produced, the project team will undertake a peer review process during the completion of tasks. The majority of the peer reviews will be conducted via consultation with other team member/s in order to verify whether the tasks has been completed within the scope of the project. Full peer reviews with the entire project team will occur prior to specific key milestones throughout the projects life-cycle. These milestones include prior to the submission of the Progress Report, at the completion of the code writing process, after constructing the groundwater software prototype, after the analysis of the results and prior to the submission of the Final Report.

8 Product Descriptions

8.1 MATLAB Scripts

The MATLAB scripts product refers to the construction and development of the code for the groundwater simulation model. This development will entail mathematically breaking down the physical phenomenon within the system and writing specific computer scripts to model each of these physical characteristics as well as the intrinsic properties of the soil layers. The benefit of this mathematical breakdown of the systems variables is that a more accurate representation of real world flow of groundwater within the region of interest can be simulated. A few example of the type of physical characteristics that will be modelled during the simulation are the town pumping rates, saturation of soil, initial boundary conditions across the region of interest and extraction rate of water from the CSG plant. The development of the MATLAB scripts will be distributed to all team members. A review of the work produced will be conducted iteratively by the entire team.

8.2 Predicted Rainfall Model

A predicted rainfall model will be created in order to simulate the rainfall over the region of interest into the future. This product will incorporate data of monthly rainfall for the region of interest obtained from the Bureau of Meteorology. A statistical analysis will be used to interpolate the existing rainfall data for any missing data entries and a method will be used to extrapolate the data for future rainfall. This model will incorporate existing patterns of dry/wet season of the region and introduce periods of drought/excessive rainfall into the predicted forecast.Sam Dudley, Neco Kriel and Aidan Cowman are the team members who are responsible for this product. The model will be reviewed progressively during its formulation by Sam, Neco and Aidan, and a final peer review will be conducted by the entire group at two key milestones: prior to the submission of the progress report and prior to the implementation of the rainfall model into groundwater simulation software. Evaluation of the appropriateness of the rainfall model will be made as a group during simulation runs of the groundwater simulation software towards the end of the projects lifecycle.

8.3 Project Management Deliverables

The project management deliverables product refers to the production of a project management report specifying expectations surrounding the production of the groundwater simulation software and analysis of the results. This report will go into detail in regards to the purpose of the project, the aim (scope) of the project, what products are expected to be produced and who will be producing these products, a schedule of the lifetime of the project and when key milestones are expected and identification of the associated stakeholders and their expectations surrounding the project. The team member responsible for the production of this product will be Dale Hebbard. The approach to this product will initially be an agile approach in order to accommodate for variations in scope of project, and expectations on delivery of products. The final Project Management Plan will be peer reviewed by the entire group prior to the submission of the Progress Report and another peer review will be conducted prior to the submission of the Final Report.An updated version of the Project Management Deliverables will be provided at the end of the projects lifecycle with an inclusions of a Lessons Learned section. This updated report will be peer reviewed by the entire project team prior to the submission of the Final Report.

8.4 Groundwater Simulation Software

The groundwater simulation software will be a prototype software that models the groundwater flow of the region of interest. This model will incorporate both the MATLAB scripts product and the predicted rainfall model in order to simulate the flow of groundwater whilst accommodating for physical phenomenon present within the system and the influence rainfall has with the replenishment of the aquifer. Simulations with changes to certain parameters (i.e. change to domestic water consumption, introduction of a CSG plant) will be able to be run to determine the impact these variations have on the stability of the aquifer system. Work on the software will be a combined group effort, with the group consulting on a weekly basis and peer reviewing the final product towards the end of the project lifecycle.

8.5 Analysis report

An analysis report will be produced discussing the findings from the simulations of the groundwater system. This report will go into depth of the influence certain variables have on the stability of the groundwater system, the impact changes to these variables induce to the aquifer as well as provide recommendations on the best practices to be followed to mitigate potential groundwater risks/issues. The formulation of the analysis report will be shared between Dale Hebbard and Aidan Cowman, with consultation between Sam Dudley, Mitchell Johnson and Neco Kriel occurring on a weekly basis and a final peer review to be conducted prior to the project deadline date.

9 Product, Work and Operations Breakdown Structures

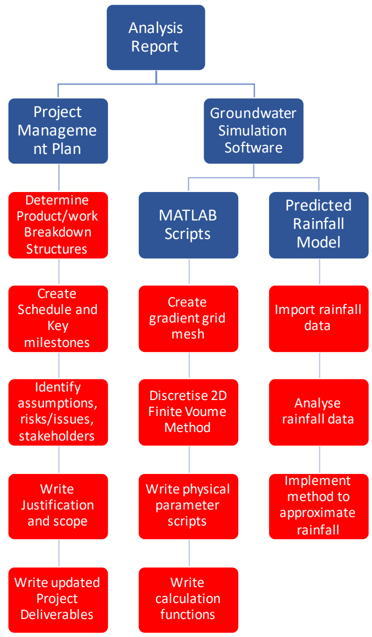

Figure 1: Figure 1: The figure shows the breakdown of the different products that will be produced and the work required to produce those products.

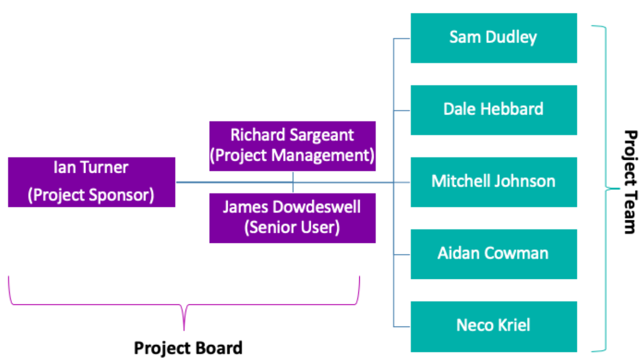

Figure 2: The figure shows the organisational work breakdown. This figure identifies the project team, the project board and the role each of the members of the project board. The hierarchy is structed reading left to right, with the head project sponsor (Ian Turner) at the top of the project hierarchy.

RACI Diagram of Project Deliverables

Project Devliverables	Sam Dudley	Dale Hebbard	Mitchell Johnson	Aidan Cowman	Neco Kriel	Ian Turner	James Dowdeswell	Richard Sargeant
	Project Team					Project Sponsor	Senior User	Project Manager Coordinator
Primary Phase Tasks	Legend: (R)esponsible, (A)ccountable, (C)onsulted, (I)nformed							
Construct a 2D mesh grid			R,A	R,C		C,I		
Discretise 2D Finite Volume Method	R,A				R,C	C,I	C,I	
Write parameter scripts	R,A	I	R,A	I	R,A	I		
Analyse rainfall data	R,C	I	I	R,A	C		C,I	
Write rainfall model approach	C			R,A	C		C,I	
Identify boundary and initial conditions	R,A				C	C,I		
Construct project shedule		R,A		C				C,I
Write Project Managemnet Plan	I	R,A	I	I	I			C,I
Write Progress Report	R,I	R,I	R,I	R,I	R,I	I	I	I
Secondary Phase Tasks								
Construct predicted rainfall model	C	I	I	R,A	C		C	
Construct Groundwater Simulation software	R,A	C	R,A	C	R,A	C,I		
Analyse simulation results	I	R,A	I	R,A	I	C	C	
Write an analysis report on simulation results	I	R,A	I	R,A	I	I	I	I

Figure 3: RACI Diagram of Project Deliverables. The diagram shows the roles different team members have in the various tasks of the project

10 Project Schedule

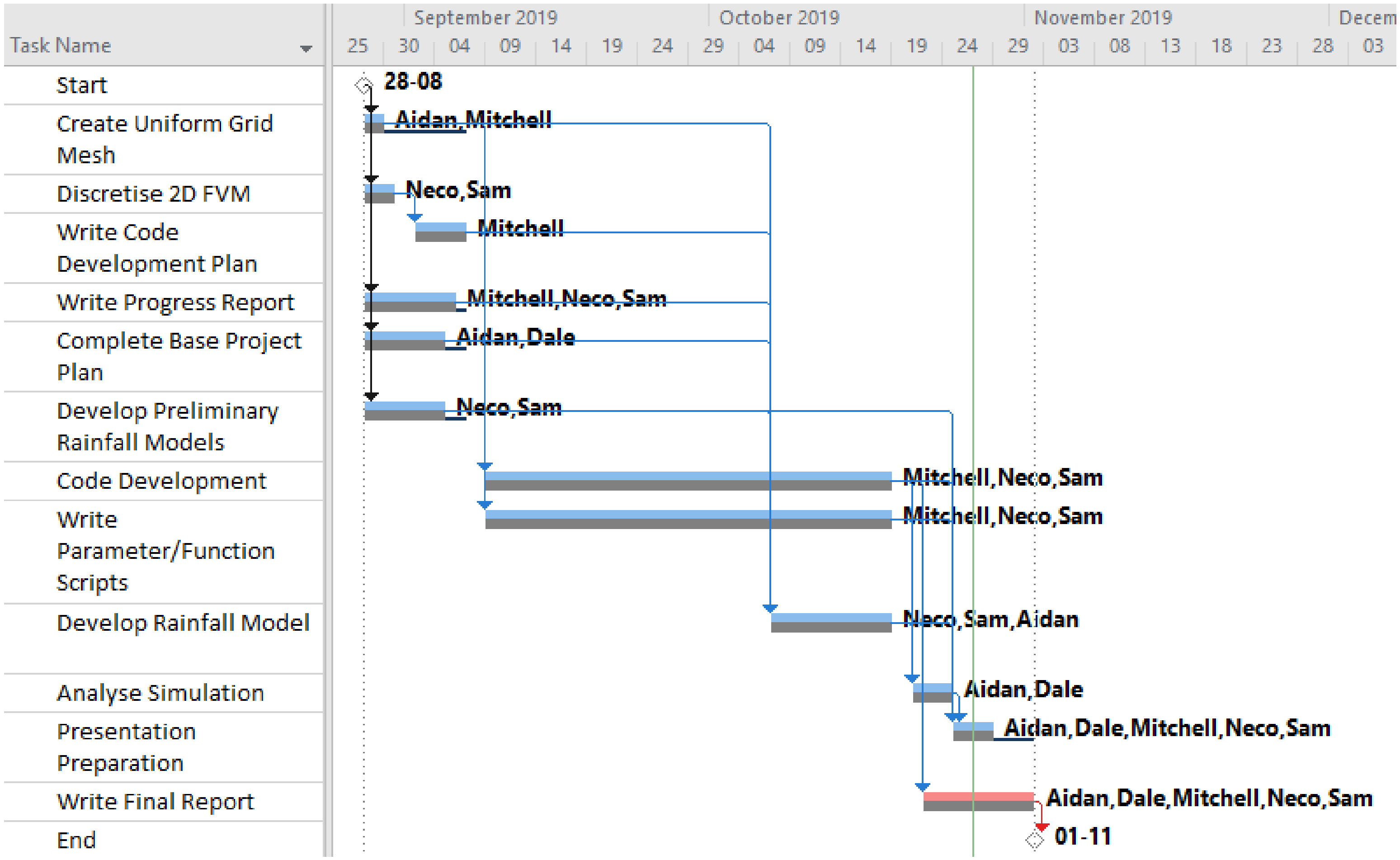

Figure 4: Updated Project Schedule and Revised Baseline

Key Milestones	Date Due
Progress Report	6th September
Development of Code	21st October
Analysis of Results	24th October
Presentation	28th October
Final Report	1st November

Table 1: Table of Key Milestones throughout the project's lifecycle

11 Risk and Issues Management

11.1 Risk

As a result of the team never having built a groundwater simulation before, it is plausible there will be misinterpretations of what is required of the simulation model which would result in the project not meeting the quality acceptance criteria. In order to reduce the misinterpretations on the model simulation being built and increase the quality of the product, it is vital that the team reach out to appropriate stakeholders for clarification of issues that arise as well as to maintain a constant stream of communication so that both the stakeholder and the team are on the same page throughout the development of the product.

Another risk involved with the production of the groundwater simulation software is inaccuracy in the predicted rainfall. The predicted rainfall model will be constructed by extrapolating the data obtained from the Bureau of Meteorology and implementing an appropriate method to predict monthly and yearly rainfall averages. There is consequently an inherent risk due to the unpredictability of future rainfall and subsequently the groundwater simulation software (which forecasts future rainfall via the constructed rainfall model) may . To minimise the inaccuracy of the rainfall, a more elaborate method will be used to extrapolate the past rainfall so that there is a higher probability of future rainfall conforming to the proposed model.

11.2 Issues

An issue that arises during the processing of the rainfall data obtained from the Bureau of Meteorology is that there are missing data points for monthly and yearly rainfall within the data. This raises an issue when attempting to model future rainfall by extrapolating from past rainfall data. To combat this risk, a statistical model will be used to extrapolate the missing data based on the preceding and following years surrounding the missing data points.

Another issue involved with the development of the project is the limited amount of contact time with stakeholders. Due to the nature of the project, interaction with stakeholders (as well as the company) is limited to certain periods throughout the projects lifecycle. This may ultimately lead to misinterpretations on the specifications of certain tasks and expectations required from the project team. To accommodate for this issue, it will be advised that the project team contact the project stakeholders for clarification/verification of any ambiguity when completing the project (via email, personal meeting, etc.) so that the companys expectations of the project are satisfied.

12 Stakeholders

The GHD company will be a stakeholder for this project as the development of the software will be attributed to them if deemed appropriate. It is therefore necessary to keep this stakeholder up to date and informed of any issues or problems that arise during the implementation of the simulation. According to the interest-influence matrix, this stakeholder is deemed to be both high in interest and influence of the project. Expectations by this company will be that the model simulation accurately predicts the fluctuation of groundwater flow due to the introduction of the CSG plant and that the simulation accommodates all expectations of other stakeholders.

The local government of the Canning Downs region is another stakeholder of this project due to the region of interest encapsulating the governmental area. It is expected that the local towns domestic supply, agricultural needs, industrial requirements and the introduction of the CSG plant will be the main topics of interest for the local government as a stakeholder. From the Stakeholder Matrix, the local government is a stakeholder with high influence and little interest (in terms of the development of the simulation), thus the best approach of management will be to anticipate and meet the needs already expressed from their expectations of the project.

The environmental legislation is responsible for the protection of the local ecosystems/flora and fauna are identified as a stakeholder of this project. This legislation will have the expectation that the short and long term impacts of the construction of the CSG plant will not have any dire consequences to the current ecosystems. It will also be expected that if the CSG plant is constructed and repercussions are present within the ecosystems, recuperation techniques will be available to mitigate the negative impacts. In accordance to the Stakeholder Matrix, it is evident that the environmental legislation has both a high interest and high influence on the development and analysis of the project. Subsequently, it is important that the appropriate representatives of the environmental legislation are kept up to date with the results of the groundwater simulation analysis and that any concerns or issues are clarified and resolved.

The company constructing the CSG plant have also been identified as a stakeholder as they have a vested interest in the construction of the plant in the local area. The expectations from this stakeholder is simply that they are authorised to build the CSG plant. It is evident that this stakeholder has a high interest on the results of the groundwater simulation but little influence on the development of the project. It is recommended to interact with this stakeholder by keeping them informed with the progress and results of the project.

13 Acceptance Testing

During the lifecycle of the project, it will be highly important to be able to identify whether the products produced satisfy the stated requirements and that these products accommodate all of the expectations expressed by the stakeholders. In order to determine the capabilities of the products, verification via peer review will be implemented. As mentioned in the Broad Approach Section, an agile approach to the project will ensure that there is constant peer review of the tasks being completed. The majority of these peer reviews will be conducted by a simply consultation with the appropriate group members to determine if the completed task satisfies the anticipated requirements. More involved group peer reviews will occur prior to the major key milestones present within the projects schedule; namely prior to the Progress Report submission, completion of the predicted rainfall model, during the finalisation of the MATLAB scripts/commencement of the groundwater simulation software and finally prior to the Analysis Report submission.

Validation of the products produced will be identified by consultation with stakeholders as well as reasonableness with physical phenomenon within the region of interest. The main validation assessment will be done through consultation with the appropriate industry stakeholders. This will provide communication on whether the current progress is in line with the stakeholders expectations and keeps the stakeholders up to date on the development of the project. From these consultations, readjustment of the projects scope or reclassification of the projects purpose can be made.

In regards to the predicted rainfall model, validation of this product will be assessed by whether the model simulates yearly rainfall patterns observed in the Canning Downs region. These patterns will include a fluctuation of rainfall corresponding to wet/dry seasons, retain a similar yearly average rainfall to the data obtained from the Bureau of Meteorology for the region as well as allowing for periods of drought. Comparison of the predicted rainfall model to other techniques to model rainfall (e.g. sinusoidal wave model and auto aggressive model).

For the script prototypes, validation of these scripts will be assessed by whether they simulate the physics of the system. Appropriately. Analysis on whether the code implements the physics of the system correctly will be used to assess the validity of the scripts. Validity of the scripts will also be assessed by the computational cost of the groundwater simulation, with a model that is too computational expensive not valid.

14 Lessons Learned

There were two major lessons learned from the completion of this project. The first of which was the importance of open and honest communication. In order for a team to work in a synergistic manner, effective communication is vital. During the lifecycle of this project, our team felt the consequences of not using open and honest communication first hand. The consequence of not communicating effectively ultimately resulted in the progress of the project coming to a complete stop for a day. Due to this halt on progress, the team organised a meeting with a third party mediator to help find a resolution to our problem. From this meeting, the team was able to reconcile and express openly and honestly how each member was wanting to move forward.

This effective style of communicating allowed the team to get back on track and continue progress for a short time period. However, communication issues arose again right at the end of the project that impacted upon the work. The lesson learned from this experience is that it is vital that every team member feels comfortable in communicating any problems, issues or uncertainties that arise during the project's lifecycle.

The second lesson that was learned from this experience was the necessity to keep in regular contact with the relevant industry partners. Due to the timeframe of the project being quite long, it was very easy for the group to lose scope of the overall project itself. Additionally, as a consequence of the project being quite complex with many different components needing to be completed, it was very easy for the group to fall behind schedule. In order to minimise this risk, the group ensured that they attended every lecture/lectorial/workshop so that we were in contact with some of the industry partners every week. This allowed us to be able to verify work that had already been completed and check whether certain approaches to tasks were appropriate and within scope.

References

[1] *The United Nations World Water Development Report 2015: water for a sustainable world.* United Nations Educational, Scientific and Cultural Organization, 2015.