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DESIGNING, TENDER COMPILATION, CONSTRUCTION SUPERVISION AND COMMISSIONING OF PILOT GROUNDWATER DESALINATION PLANTS AT GRÜNAU AND BETHANIE WATER SUPPLY SCHEMES, //KARAS REGION

DRAFT
TRAINING REPORT

SEPTEMBER 2021

SUBMITTED BY:

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Process Engineer...................................
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TRAINING REPORT

DESIGNING, TENDER COMPILATION, CONSTRUCTION SUPERVISION AND COMMISSIONING OF PILOT GROUNDWATER DESALINATION PLANTS AT GRÜNAU AND BETHANIE WATER SUPPLY SCHEMES, //KARAS REGION

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ANNEXURES

1 INTRODUCTION

Knowledge transfer as well as capacity building was implemented throughout the entire project especially during the design stage of the project. The consultant transferred knowledge and skills on combined small scale RO technology and hybrid renewable energy to effectively and efficiently desalinate poor quality groundwater.

Design of water treatment systems can be complex. In many cases the process and plant design is based on theory but is “built” on experience. This is because treatment sites tend to be unique when considering the information available, or lack thereof, the specific site constraints involved and the specific needs of the client and end users. The best way to learn is to do. The individuals who picked up elements of the skill set were already competent in the basic sciences of hydraulics, and chemistry. Additionally, the knowledge transfer was aimed at novice designers (chemical/process, electrical/electronic, mechanical, and civil/structural). The candidates’ CVs were shared with the consultant for agreement to ensure that the contact was meaningful. The numbers were also limited to no more than six officials to ensure that the knowledge share load did not place undue pressure on the professional team whose primary focus was on delivering the project. The training was focused on the specific plants involved in this project.

Contact consisted of electronic communication and face-to-face meetings. Electronic contact was via Skype and email. Office space was also made available during the training period for NamWater officials to have personal contact with respective mentors. The contact and information exchanges consisted of:

- Sharing of information pre-engagement.
- A brief introduction to the specific topic of focus.
- An exercise for the officials to complete consisting of:
    - Reading work;
    - Completion and submission of a short assignment based on the reading work which may include developing of spreadsheets or similar
- Assessment of the assignments and feedback.

Training presented was not accredited in any manner. The training was considered to be an expansion of the official’s current “on-job” and “day-to-day” learning experience.

Topics addressed during the knowledge share encounters were structured around the project and the work processes required realising such treatment plants. The following engagement topics were included:

- Assisting collecting all relevant information;
- Studying all existing information;
- General water treatment concepts;
- General background on membranes;
- Water quality;
    - Data selection and interrogation
    - Definition of treatment targets
- Membrane treatment process selection;
- The role of specialist suppliers;
- Understanding the concept design and plant processes;
- Site visits;
- Earned Value Management Methodology;

- Finite Element Analysis;
- Assessment of example preliminary design calculation;
- Understand evaluation of alternatives (cost and environmental considerations);
- Clear understanding of the preliminary design;
- Assessment of example final design calculation;
- Specification of equipment;
- Study of all final drawings and all specifications;
- Accompany construction supervisor engineer on site visits;
- Study working drawings from contractor;
- Accompany engineer team during testing and commissioning;
- Study all relevant equipment manuals;
- Understand the overall operating philosophy of the plant;
- Study all operating and maintenance manuals; and
- Assessment of the day to day operation of the membrane plant

2 ATTENDEES AND MENTORS

The engagement began with the provision of the names and CV's of candidates from where a list of the officials was drawn up, as shown in the table below.

Table 1: Training Program Trainees and Mentors

Trainee	Gender	Position	Area of Training	Mentor	Gender	Discipline
Beatha Nelenge	Female	Chemical Technician	Water Quality and Membrane Plants	Dr Tony Ceronio	Male	Process
Penehafo Ndakalako	Female	Chemical Technician	Water Quality and Membrane Plants	Dr Tony Ceronio	Male	Process
Selma Shilongo	Female	Civil Engineer	Evaporation Pond Design, Pipelines, Foundations, Water Quality, Fencing	Felix Kuchling	Male	Civil
Meitavelo Kayofa	Male	Mechanical Engineer	Pump an Piping Design, Instrumentation, Solar and Wind Energy, Heat Load Estimate, Contract Administration	Holger Rusch	Male	Mechanical
Oris Mulonga	Male	Electrical Engineer	MCC design, Surge and Lighting Protection, Instrumentation, Controls, Solar and Wind Energy, LV Reticulation	Anke Rusch	Female	Electrical and Electronic
Petronella Buys	Female	Civil Engineer	Evaporation Pond Design, Pipelines, Foundations, Water Quality, Fencing	Felix Kuchling	Male	Civil

3 DESIGN STAGE

3.1 Session 1

3.1.1 General

The first session included a general discussion of the project and took place at the consultant's offices on 13 February 2019 after the Concept Design Report was completed. The attendance list is included in **Annexure A** of this report. The session included all the sectors of the water treatment plant and hybrid renewable energy plant and covered the following topics:

- Inception and Concept Design Reports
- RO Membrane Plant Introduction
- Applicable Services to the Mechanical, Electrical, Civil, and Process Installations
- Introduction to Water Quality
- Introduction to Reverse Osmosis
    - Cross Flow Operation
    - Mass Balances
    - Recovery
    - Rejection
    - Osmotic Pressure
    - Hydraulic Pressure
    - Flux
- Introduction to Photovoltaic (PV) Installations
    - Types of PV Systems
    - Overview of Components
    - Electrical Power Obtained
- Introduction to Wind Turbine Installations
    - Wind Speed
    - Overview of Components
    - Electrical Power Obtained
- Introduction to Brine Disposal
- Introduction to Cost Analysis
    - Net Present Value (NPV)
    - Discount Rate
- Introduction to Ecology Analysis
    - Carbon Footprint
    - Energy Yield Ratio
    - Energy Payback Time

3.1.2 Further Reading and Useful Resources

The following reading material was provided to the participants:

- C Fritzmann, J Löwenberg, T Wintgens, T Melin, 2006. *State-of-the-art of Reverse Osmosis Desalination*, Aachen, Germany: Elsevier
- G Olsson, 2018. *Clean Water Using Solar and Wind Outside the Power Grid,* London, England: IWA Publishing
- W Tong, 2010. *Chapter 1: Fundamentals of wind energy*, Virginia, USA: WIT Press

The following useful resources were also provided:

- **PVGis** Solar Database: Worldwide database which offers TMY (Typical Meteorological Year) data, including hourly direct normal irradiance (DNI), diffuse horizontal irradiance (DHI), ambient temperature and wind speed values. <http://re.jrc.ec.europa.eu/pvg_tools/en/tools.html>
- **SASSCAL WeatherNet** Weather Database: weather database of actual measured weather data for several weather stations across Namibia. <http://www.sasscalweathernet.org/index.php>

3.1.3 Assignment

Each of the different services namely: Process, Mechanical, Electrical, and Civil was given assignments. Each assignment is given in **Annexure B** as well as the assignment's evaluation.

3.1.4 Additional Courses

The consultant also provided information on the following online courses to the trainees:

- *Nanofiltration and Reverse Osmosis in Water Treatment* by Delft University of Technology (TU Delft) online learning <https://online-learning.tudelft.nl/courses/nanofiltration-and-reverse-osmosis-in-water-treatment/>
- *Solar Energy: Photovoltaic (PV) Systems* by Delft University of Technology / edX <https://www.edx.org/course/solar-energy-photovoltaic-pv-systems>
- *Wind Energy* by Technical University of Denmark (DTU) / Coursera <https://www.coursera.org/learn/wind-energy>

3.2 Session 2

3.2.1 General

This session was completed after the preliminary design report was completed and was done separately for each service i.e. process, mechanical and electrical, and civil. These sessions took place at the consultant's offices on 20, 21, 23 and 27 May 2019. The attendance list is included in **Annexure A** of this report.

3.2.2 Process

Generally the session went through the preliminary design of the consultant and addressed the water treatment in general which included water quality, mass flow balance, pre-treatment, membranes, post-treatment, recovery flows, etc. The results and answers of Assignment 1 and 2 were also discussed and feedback was provided to the trainees.

Furthermore the pre-treatment, in this instance granular filtration, was discussed in depth which included, pressure filtration, filtration media, backwash, etc. The trainees were given an assignment on filtration (Assignment 3).

The following additional reading material on filtration was also provided to the trainees:

- A D Ceronio, J Haarhof, 1997. *Properties of South African Silica Sand used for Rapid Filtration*, South Africa: Water SA
- J C Crittenden, 2005. *Water Treatment: Principles and Design, 2nd Edition,* J. Wiley, pp. 887-903
- A D Ceronio, J Haarhof, 1994. *Die Evaluasie van Suid-Afrikaanse Filtermedia vir Diepbedfiltrasie*

3.2.3 Mechanical and Electrical

Generally the session went through the preliminary design of the consultant and addressed the mechanical and electrical / electronic services for the water treatment plant as well as the hybrid renewable energy plant. The results and answers of Assignment 1 and 2 were also discussed and feedback was provided to the trainees.

It was evident from our discussion that the trainees were very familiar with pump and piping designs, instrumentation design, motor control centre (MCC) design, surge and lighting protection, controls, low voltage (LV) reticulation. It was therefore decided to just discuss these in general and to put more emphasis on the other services such as renewable energy and the RO system.

Energy recovery systems for the RO plant was also discussed and reasons for why this may not be feasible for such a small plant and low brine flow. Calculations were also done on the energy recovery system for the plants which confirmed the reason for exclusion.

Innovative technologies to increase the evaporation pond efficiency were also discussed; however, most of these were also discarded due to the higher energy requirements of the technologies.

The following additional reading material was also provided to the trainees and discussed:

- A Smets, K Käger, O van Swaaij, M Zeman, 2016. *Solar Energy: The Physics and Engineering of Photovoltaic Conversion, Technologies and Systems*, England: UIT Cambridge
- S Hoque, T Alexander, P L Gurian, 2008. *Innovative Inland Brine Disposal Options*, American Water Works Association

3.2.4 Civil

Generally the session went through the preliminary design of the consultant and addressed the civil design (mostly the evaporation ponds). The pond liner material and alternatives were also discussed in detail and the trainee provided details on alternatives to the consultant.

The following additional reading material on filtration was also provided to the trainees:

- B Ladewig, B Asquith, 2012. *Desalination Concentrate Management Capter7: Evaporation Ponds*, Springer, pp. 49-57
- M Ahmed, W H Shayya, D Hoey, A Mahendran, R Morris, J Al-Handaly, 2000. *Use of Evaporation Ponds for Brine Disposal in Desalination Plants*, Elsevier

3.3 Session 3

3.3.1 Process

Generally the session was allocated for the process services of the water treatment plant. The attendees attended the session at the consultant's offices on 19 July 2019. The attendance list is included in **Annexure A**. However, the mentor, Tony Ceronio, completed the session via video conferencing. The consultant went through the final design and put emphasis on the membrane process. The following topics were addressed:

- Preliminary selection of membrane material
- Membrane pre-treatment
- First order membrane plant design
- Membrane design using software

A link to download the membrane selection software as well as the manual was provided to the trainees.

The trainees were given an assignment on the reverse osmosis process (Assignment 4). The assignment is given in **Annexure B** as well as the assignment's evaluation.

4 CONSTRUCTION AND SUPERVISION STAGE

4.1 Session 4

4.1.1 General

Two sessions were held one for civil engineering and one for mechanical and electrical engineering. This took place on 24 and 30 January 2021 respectively; refer to **Annexure A** for attendance lists.

4.1.2 Civil

Generally the session went through the final design of the evaporation ponds in detail and the optimisation of the ponds' sizes and number of ponds required. This was more a design session; however, was done after the contractor was appointed and therefore discussed under the construction stage.

The trainee was provided with an assignment, which is again included under **Annexure B**.

4.1.3 Mechanical and Electrical

For this session the trainees indicated that they are interested on the project management part of the projects and the discussions revolved around earned value management (EVM). The trainees were provided with the contractor's Gantt chart as well as completed bill of quantities to complete the EVM, as discussed.

The trainees were also provided with and assignment with regards to EVM. The assignment and evaluation on the feedback are included in **Annexure B**.

During the discussions reference was made to the following:

- J Rakos, 2005. *The Practical Guide to Project Management Documentation*, John Wiley and Sons, pp. 226-232

4.2 Session 5

4.2.1 General

Again this session was about the detail structural design of steelworks of the plants; however, was done after the construction commencement. As the trainees were familiar with water projects, due to the nature of their everyday work, they requested that the session revolve around an unfamiliar subject which was also part of the plants. Finite element analysis (FEA) was proposed and accepted as an alternative subject.

Two trainees were interested and the session took place at the offices of the consultant on 18 February 2020. The attendance list is included in **Annexure A**.

The discussion was mostly about using FEA software to solve solid mechanic problems. The trainees were provided with and assignment with regards to FEA. The assignment and evaluation on the feedback are included in **Annexure B**.

The consultant also provided information on the following online course to the trainees:

- *Hands-on Introduction to Engineering Simulations* by Cornell University / edX <https://www.edx.org/course/a-hands-on-introduction-to-engineering-simulations?index=product&queryID=df32904729be127cf08c70b39bc6a391&position=1>

4.3 Supervision

4.3.1 Grünau

Most of the water treatment and renewable hybrid energy plant was constructed in Windhoek. This was convenient for all the trainees and regular visits were made to the plant construction to inspect the container. This was approximately done for every month while the containerised plant was assembled in Windhoek.

Once the container was moved the trainees frequently visited the site during the construction period when site contract meetings took place. All trainees were invited to site meetings and as mentioned before most attended the site meetings.

During these visits and meetings the trainees where taken through the different services and everything was explained to them. There was also question and answer sessions where the consultant and contractor tried to answer all questions from the trainees.

Trainees also attended the SCADA / Reporting demonstrations by the contractor.

Again the trainees were already well educated on water treatments plants due to their past experience and day to day work activities.

4.3.2 Bethanie

Unfortunately the Bethanie plant had been constructed on site due to the size of the plant and most of the site visits were missed by the trainees due to other previous engagements and because of the travel restrictions due to the COVID pandemic.

Trainees did attend virtual site / contract meetings; however, as mentioned before due to the above mentioned unfortunate events actual time spend at the construction site were very low.

Also the two plants are very similar with only the scale being different it is assumed that most of the trainees' questions where already answered during the construction of the Grünau project since the Bethanie project lagged the Grünau one.

4.3.3 Commissioning

The commissioning / final report was also provided to NamWater for information. An informal session with one of the process trainees was also scheduled with regards to the verification that the water treatment plant is running according to the design parameters on 13 August 2021. During the meeting the final report of Grünau was discussed and the plant operation with regards to the normalised pressures, normalised flows and normalised total dissolved solids (TDS) were discussed. It was agreed that the trainee will also check the logged data from Bethanie and the results will be compared to that of the consultant.

5 INFORMAL TRAINING SESSIONS

Several informal training sessions took place either during informal scheduled sessions, e-mail, or video conferencing during the project period where questions were answered, assignments were discussed, and other alternative design and processes were discussed

6 CONCLUSION

The project was a learning experience to all; the consultant included, and valuable experience was obtained and transferred. It was clear that the trainees already had good experience in the field of water treatment and auxiliary processes due to the nature of their daily work and previous projects completed. The project gave the trainees the opportunity to reiterate the experience already obtained and to learn something new especially with regards to renewable energy supplies and membrane technology.

The assignment feedback was in general fair with several assignments not completed due to the trainees other work commitments. However, the feedback that was returned showed that the trainees had excellent understanding of the tasks and the assignments were completed well.

As mentioned before the consultant also obtained invaluable experience during the project. Not just because of the nature of the work but also during the interaction between the consultant and the trainees. The consultant also build a good relationship with the trainees and any further queries the trainees may have on the project or other similar projects would happily be answered or tried to be answered by the consultant.

In conclusion the consultant is under the opinion that the project did meet the objective to provide invaluable experience on the renewable energy RO plants, especially in a drought stricken country such as Namibia.

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REPORT APPROVAL

This training report is submitted to the Head: Research and Development as a deliverable under project, Pilot Desalination Plants Using Renewable Energy Phase 2 (C-HGMO315).

....
Project Manager: Programme Management

Date: ....

This training report has been completed to the satisfaction of the Research and Development Department in accordance with the requirements of the project and I support the recommendations contained in this report.

....
Head: Research and Development

Date: ....

This training report has been discussed by interested parties within NamWater and the recommendations contained in the report are approved by NamWater.

....
In the capacity of **Chair: Progress Meeting**

Date: ....

ANNEXURE A:

ATTENDANCE LISTS

ANNEXURE B:

ASSIGNMENTS AND MENTOR EVALUATIONS

<u>PROCESS</u>

<u>Assignment 1</u>

1. Calculate the allowable percentage blend water to meet the minimum Namibian National Standard (DWAF, 2011) assuming recovery rates from the RO of 65 %, 75 %, and 95 %. The flow rates and water quality reports can be found in the concept design report.

Feedback from trainees was provided to the client electronically.

Evolution of Assignment 1 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment					X
2. Trainees' Feedback					X
3. Brief Summarized Report					
4. Presentation					

Date ------------------------------ Signature Mentor ------------------------------

Assignment 2

a) Percentile calculations

Use the water quality data for Grünau (as attached). By deriving percentile values for various intervals (50th, 75th, 90th, 95th and 99th percentiles), evaluate and compare the turbidity data for each of the following scenarios:

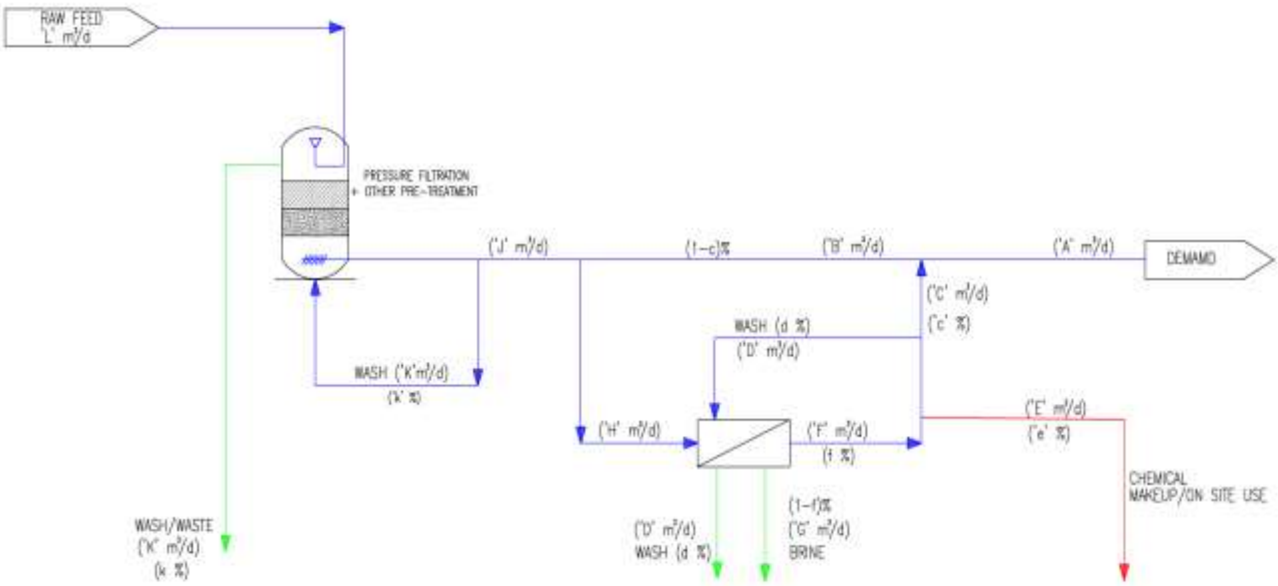
- All of the turbidity data combined
- Separately for each of the sample points (Reservoir, WW23404, WW23405, WW23406, WW23407, WW33890 and WW33891)

Given the analysis performed above with respect to turbidity only, postulate risk scenarios in the Grünau system resulting in non-compliance and the possible interventions that can be employed.

b) Membrane plant sizing

The diagram below is a first order description of the Grünau. The following applies for the purposes of this exercise:

- Raw feed is limited to 47.5 m³/d
- The demand is 36 m³/d
- Filter wash and waste is expected to be 5 % of the flow through the filter.
- Brine discharge from the membrane can vary between 15 and 40 % of the flow through the membrane. Membrane recovery will therefore vary between 60 to 85%.
- 5 % of the membrane production will be needed to rinse the membrane on shut-down.
- A further 5 % of membrane production will be needed for chemical make-up and on-site usage
- The F- level in the raw feed is 3.0 mg/l.



Determine the minimum membrane recovery that must be achieved in order to meet the consumers demand under the following conditions:

- The F- concentration in the membrane permeate is 0.2 mg/l

- The F- concentration in the membrane permeate is 0.6 mg/l
- Provide the hydraulic balance for the two cases investigated. This is, provide the values for A, B, C, D, E, F, G, H, J, K and L.

Feedback from trainees was provided to the client electronically.

Evolution of Assignment 2 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment					X
2. Trainee's Feedback					X
3. Brief Summarized Report					
4. Presentation					

Date

Signature Mentor

Assignment 3

Instructions:

- Study the WaterSA paper on the properties of South African silica sand as used in rapid gravity filtration. Also refer the WRC report No 472/1/94 for additional information.
- Study the extract from "Water Treatment Principles and Design – Second edition"
- You are also welcome to use other references as long as these are referenced in your response.

Using the information found in these documents or other references, answer the questions below using the media grading data (below) as typically received from a laboratory:

	Sample 1	**Sample 2**
Sample mass	156.09 g	143.09 g
Sieve aperture (mm)	**Mass retained**	**Mass retained**
1.40	0.09	0.00
1.18	5,66	0.14
1.000	61.76	7.15
0.850	49.14	25.74
0.710	29.73	35.75
0.600	6.55	45.55
0.500	1.90	35.54
0.425	0.48	5.72
Pan	0.16	0.14

Additionally the laboratory has advised that:

- the porosity (ε) of the media grains is 0.55, and
- the density of the silica (ρ_s) is 2 650 kg/m3.

a) Media size characteristics

i. Derive a media grading curve in order to determine the effective size and uniformity coefficient.

ii. Comment on the weight loss during the grading analysis. Is this acceptable?

iii. Using the relationships established by Wen & Yu (1966) as described in the references provided, determine the sphericity of the media (ψ) for the media samples.

iv. Is there a problem with the concept of media grain sphericity? Please expand.

v. Assume the media bed made up of these media samples can be described of 5 discrete layers, each of equal depth and consisting respectively of 20% of the media mass. By reading the media sizes for d_0, d_{20}, d_{40}, d_{60}, d_{80} and d_{100} from the curves you have prepared, determine the geometric mean (d_g) size for each of the layers. Do this for each media grading.

vi. Does Namwater have an internal silica media specification it uses to top up media on its current plants? If so, compare both samples to the specification and advise how this compares with the Namwater specification.

b) Energy loss during filtration

Using the Ergun equation from the WaterSA article develop a spreadsheet to calculate the energy loss in the filter media based on the following assumptions:

- Assume the filter bed depth is 0.8 m.
- Use the values for ε, ψ, and d_g determined in the preceding calculations.
- Use the Ergun equation to calculate energy loss.

Tip – the calculation will done by dividing the bed into 5 layers (as per 3a) and using d_g for each layer. The energy loss will then be made up of the 5 losses which occur in series.

i. Determine the clean bed energy losses for both media samples at 5 m/hr, 7.5 m/hr and 10 m/hr. Assume a water temperature of 20°C in all cases. Tabulate and graph the results. Comment on the effect of filtration rate on energy loss.
ii. Use only the first sample grading and repeat the clean bed energy loss calculation for 10°C, 15°C, 20°C and 25°C at 5 m/hr. Tabulate and graph the results. Comment on the effect of temperature on energy loss.
iii. Assume the bed is over compacted due to uncontrolled and rapid media settling or surge in the system resulting in a ε_{mf} of 10 % from your initial value. Determine new clean bed energy losses on the same basis as question 3.b.i above. Only do this calculation for the first media grading. Comment on the effect of porosity on clean bed energy loss.

c) Minimum fluidisation velocities (v_{mf})

Media size, media density and water temperature impact on v_{mf}. The v_{mf} of filter media can be determined using various methods of which the Galileo number approach is one – this however leads to the need to develop iterative solutions. Set up a spreadsheet using the approach presented in "Water Treatment Principles and Design". Use the spreadsheet to calculate and investigate the above mentioned variables in the following manner:

i. Determine the v_{mf} for a 0.5 mm, 0.75 mm and 1.0 mm silica grain at 20°C (ρ_s = 2650 kg/m³).
ii. Determine the v_{mf} for a 0.5 mm, 0.75 mm and 1.0 mm anthracite grain at 20°C (ρ_s = 1400 kg/m³).
iii. Determine the v_{mf} for a 0.75 mm silica grain (ρ_s = 2650 kg/m³) at 5, 10, 15, 20 and 25°C.
iv. Comment on the effect of media size, density and water temperature on v_{mf}.

d) Bed expansion

The principles of filter media hydraulics are different before and after v_{mf}.

v. Explain briefly what happens with filter media bed porosity as the backwash rates increases from below v_{mf} to beyond v_{mf}.
vi. Explain briefly what happens with the total energy loss across a bed as the backwash rates increases from below v_{mf} to beyond v_{mf}.
vii. Develop a spreadsheet and calculate the expanded bed depth at a backwash velocity of 30 m/hr for both media samples at 15°C and 25°C. Use the method prescribed in

Water Treatment Principles and Design. This reference uses typical numbers to get around the sphericity problem. Remember to split the bed into a number of layers and calculate the expanded depth per layer. You can calculate the total expanded bed depth thereafter.

No feedback was provided by the trainees.

Evolution of Assignment 3 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment	X				
2. Trainee's Feedback	X				
3. Brief Summarized Report					
4. Presentation					

Date

Signature Mentor

Assignment 4

Instructions:

- Study the literature provided. This will include sections from an American Water Works Association publication (Manual of Water Supply Practices M46: Reverse Osmosis and Nanofiltration; 2nd ed) which will be copied into this assignment as well.
- You are also welcome to use other references as long as these are referenced in your response.
- You will need to download and install free design software from Hydranautics at the following web address: http://membranes.com/solutions/software-imsdesign/

Using the information found in these documents or other references, answer the questions below.

The membrane plant design exercise is based on the hydraulic balance as determined in **Assignment 2**.

a) Preliminary selection of membrane material

Membranes are typically manufactured using cellulose acetate or polymers (polyamides). Although the latter have been developed more recently, each has advantages and disadvantages which have to be considered carefully in as an initial consideration in the design of a membrane plant as it provides guidance on the remainder of the design process. Refer the table below copied from M46 for a summary of these:

Table 1-3 Comparison of thin-film composite and cellulose acetate membranes

Parameter	Thin-Film Composite Polymer Membranes	Cellulose Acetate Membranes
Salt rejection	Higher (>99.5%)	Lower (up to 95%)
Net driving pressure	Lower	Higher
Surface charge	More negative	Less negative
Chlorine tolerance	Poor	Fair
Cleaning frequency	Higher	Lower
Organics removal	Higher	Lower
Biofouling	More susceptible	Less susceptible
Biodegradation	None	Higher
pH tolerance	High (2–13)	Limited (4–8)

viii. Consider the general constraints of the projects at Bethanie and Grünau and select a membrane material of preference. Indicate why you have selected this material.

ix. What are the main disadvantages your selection holds and how will you need to mitigate against these disadvantages in your design?

b) Pre-treatment

i. Membrane elements come in various configurations of which spiral-wound elements are by far the most common configuration used in municipal water treatment applications as hollow fibre membranes typically requires more care to prevent fouling from colloidal and suspended solids (due to the high packing density). M46 recommends the following guidelines for suspended solids to be met:

- Turbidity < 0.3 NTU

- Silt Density Index (SDI) below 4 for spiral-wound membranes (<3 for hollow fibre membranes)

Review the water quality analysis reports provided for both Bethanie and Grünau and recommend whether the process will require particulate removal before the water is applied to the membranes.

ii. The table below provides a list of options to be considered for pre-treatment. Consider which would be most appropriate for Bethanie and Grünau and provide your reasons.

Table 2-4 Pretreatment techniques (listed in decreasing order of effectiveness) for reducing silt and colloidal material

Method	Comments
Low-pressure membrane filtration (MF or UF)	Operates at low pressures and requires periodic chemical cleaning and frequent backwashing. Removes particulates but essential no organics (unless a precoagulant is fed). High solids loads may require additional pretreatment to be cost effective.
Precoat filtration	Precoat media must be added to replace losses in the backwash step. Does not remove dissolved organics. High solids loads may require additional pretreatment to be cost effective.
Coagulation/flocculation/sedimentation/ filtration	Provides the most process flexibility of all methods. Process is able to remove appreciable organics using coagulation. Highly tolerant of variable suspended solids loads.
Multimedia and pressure filtration	Pilot testing may be required to determine the best media for SDI reduction. May be used in conjunction with coagulants–flocculants, with and without settling.
Rapid sand filters and ultrahigh-rate filters	Coagulants are generally required to achieve acceptable SDI reduction, most through inline coagulation. Can handle limited high turbidity events.

iii. The table below provides a list of flocculants that are typically encountered in potable water treatment. Should you have to use a flocculant in this design, which one would it be? Why?

Table 2-5 Common coagulant–flocculants

Chemical	Comments
Inorganics	
Aluminum sulfate or alum, $[Al_2(SO_4)_3]$	Minimum solubility is achieved at pH 5.7 to 6.5 in freshwater and brackish water applications. Lower values are reported for seawater.
	Must allow sufficient time for complete precipitation or aluminum salts may deposit on membrane.
Aluminum chlorohydrate (ACH) and Polyaluminum chloride (PACl)	Highly effective coagulant results in minimal membrane fouling, effective over wide pH range (pH 5 to 8).
Ferrous sulfate, $(FeSO_4)$	Oxidation to ferric form of iron is required to be effective. Optimal pH is >8.4 for freshwater for particulate removal. Lower pH is optimal for organics reduction.
Ferric sulfate, $[Fe_2(SO_4)_3]$	Works best at ambient pH in freshwater for particulate removal. Lower pH is optimal for organics reduction.
Ferric chloride, $(FeCl_3)$	Works best at pH 6.0 to 7.0 for freshwater. Chemical is widely used for membrane pretreatment of surface water.
Organic polyelectrolytes	
Cationic	Will interact with many scale inhibitors. Can irreversibly foul many spiral-wound membranes. Consult manufacturer.
Anionic and nonionic	Will not react with most scale inhibitors. May foul certain membranes. Consult manufacturer. Generally less effective than cationic as a coagulant–flocculant.

iv. Why would you need the following chemicals to be provided as part of your pre-treatment in a membrane plant design? Also provide three typical chemicals you could under each class.

- Biocides
- Anti-scalants

c) First order membrane plant design using rules of thumb

There are several first order design approaches. The main failing of this approach is that it is not based on fundamental principles and therefore lacks all the checks and balances needed to ensure that a membrane design is appropriate. These approached however do provide a good starting point to the design. Study the literature provided in the assignment pack and pay particular attention to:

- The rules of thumb around the number of membrane stages required
- The rules of thumb around the configuration of these stages
- The various ways, other than additional stages that can be used to increase permeate recovery (and note that the rules of thumb do not specifically deal with permeate recovery).
- The design guidelines provided on RO sizing.
- The design limits provided with respect to water sources and SDI and how this impacts on flux decline.

The guidelines are fairly old. This is because the design approach has moved away from high level hand calculations to extensive use of Membrane Design Software that is available for free, firstly, and which also uses fundamental approaches which lead to more accurate results, particularly where chemistry and saturation indices play a role.

For this part of the assignment:

Do a high level concept design of the Bethanie and Grünau RO plants using the design rules provided. As input use the following:

- The flow balance calculated in Assignment 2
- The membrane product brochures provided with this assignment (ESPA2-LD for Bethanie and ESPA2-LD4040 for Grünau).

Propose at least two design options for each plant and document the following:

i. Design solutions;
ii. Your opinions and thoughts (positive and negative) on the design approach.

d) Membrane design using freeware

As indicated earlier the available software is complex and uses first order approach to RO design. There are a number of packages provided by various suppliers that perform similar design simulations and these can be used freely. This assignment is however based on the Hydranautics software. Download and install the design software using the link provided. The manual provided along with this assignment will assist in this process if needed. Set the necessary project defaults – these can be adjusted at a later stage if needed.

At the core of the design lie the selection of the number and the design configuration of the filter elements and filter vessels. This must be done in a manner that:

- Meets the water quality objective of the design;
- Meets the hydraulic constraints of the design; and
- Meets the energy objectives of the design.

These constraints are typically defined before the design reaches this stage. Refer your Assignment 2 in this regard where both water quality objectives and the required hydraulic efficiencies for the design have been defined.

NOTE:
It is unlikely that the design you prepare leading up to the tender stages of a project will be the exact one offered by the successful tenderer. This is because the tender will not (cannot) specify specific and exclusive brand names and the tenderer will source his equipment (membranes) from any number of competing suppliers which have comparable equipment. The main purpose of a membrane design at this stage is to specify a workable (and reasonably optimised) configuration from where performance benchmarks can be specified as tender requirements. It is not possible at this stage to evaluate ALL options (membrane models included) from where the absolute best design can be defined. The onus will be on the tenderer to prove that the equipment provided is capable of meeting the performance criteria as set out in the design prepared for tender purposes. His/her proposed design will be evaluated during the tender stage in order to evaluate the viability of the design alternative offered.

i. Do some research and propose alternative membrane options (supplier and model) that could be considered in the design of the two plants under consideration here. Some research is required in this regard as membrane development is rapid and models are replaced often. An internet search using keywords (name of a supplier that is locally represented; RO; low pressure; brackish water; etc.) will assist in reducing the number of options to consider. It is also helpful to discuss with local suppliers and contractors what their recent experiences, successes and failures have been related to membrane choice as a good reference provides additional certainty to the design. Remember to consider the project constraints in your research for suitable membranes.

ii. Set up a design model using the Hydranautics software:

- Input data into the software, in order to ensure treatment success under most cases, use the “worst case” 95th percentile data. Note the need for data that is not normally monitored – resolve issues where the data is not available and state your approach/assumptions in these cases.
- Set up the configuration of the plant using the membrane brochures provided along with this assignment (ESPA2-LD for Bethanie and ESPA2-LD4040 for Grünau). Use the results of your manual calculation as a starting point.
- Resolve all system generated errors with respect to your setup and run the model. Rerun the model after tweaking if your results indicate design concerns. Print a report of your design and use this as a baseline to work further from. Remember to record all issues you encounter and how this was resolved. Provide printed reports from the software on your successful design.
- Try to optimise your design (increase permeate recovery, reduce energy required, reduce hardware requirement). Compare your final design with the “rule of thumb design” and provide your comments. Provide printed reports from the software on your final optimised design recommendation.
- Consider the effect of temperature on your design. Run optimised design at 15, 20 and 25°C and tabulate the key design outcomes. State what effect temperature has on the design outcomes and state how you accommodate the findings based on temperature in your design approach.

No feedback was provided by the trainees.

Evolution of Assignment 4 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment	X				
2. Trainee’s Feedback	X				
3. Brief Summarized Report					
4. Presentation					

Date

Signature Mentor

MECHANICAL

Assignment 1

1. Obtain hourly wind speed data for Bethanie Site for at least 10 years and calculate the annual energy yield for a 1.5 kW_p, 3 kW_p, 5 $kW_{p,}$.6.7 kW_p, and 10 kW_p wind turbine.

Feedback from trainee was provided to the client electronically.

Evolution of Assignment 1 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment					X
2. Trainee's Feedback					X
3. Brief Summarized Report					
4. Presentation					

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Date Signature Mentor

Assignment 2

1. Calculate the percentile energy generated by the 10 kW wind turbine compared to the total energy required for the plant over a year if the plant requires 399 kWh per day.
2. Calculate the equivalent amount of PV panels required for the same amount of energy generated by the 10 kW wind turbine, taking the following in account:
    a. Peak Power of 1 PV panel = 315 W; and
    b. Average sun hours available / day = 4.8 hrs.
3. Compare the initial installation cost of the PV installation to wind turbine installation, taking the following in consideration:
    a. Cost of material and installation of 1 PV panel = N$ 3 500.00; and
    b. Cost of equipment and installation of 10 kW wind turbine = N$ 320 000.00. (This is on the low side and was estimated by the consultant and may be higher due to the remoteness of the site)
    c. The above preliminary calculations did not take into account the topography (relative high for Bethanie taking a surface roughness length of 0.15 m) nor sheltering effect (can decreased the wind speed with up to 60 %). Due to the fact that these parameters are impossible to calculate theoretically and if we assume that the wind energy is decreased with a further 25 % (this is conservative and may be higher in reality) what will be the effect on the above?
4. Present the above in a power point presentation to us and NamWater.

No written feedback was provided by the trainee; however the trainee did provided verbal feedback.

Evolution of Assignment 2 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment					X
2. Trainee's Feedback			X		
3. Brief Summarized Report					
4. Presentation	X				

Date

Signature Mentor

Assignment 3

Please construct a spreadsheet (additional sheet) to reflect the current Gantt Chart of NEC (contractor).

Your Gantt chart must include the following:

- **Planned Value** (PV) for each task / milestone. This can be obtained from the BoQ items allocated to each task. Obviously this will differ for each of you depending on which item you allocated to each task / milestone. Therefore, allow for an additional column in you Gantt Chart for PV value for each task / milestone. This is the same that was done for the Project Funds Utilisation.
- Completion column in % to indicate progress of each task. From this you bust be able to calculate the Earned Value (EV). Also include a column for EV. Obviously this is zero for most tasks at this stage.
- **Actual Cost** (AC) column. This amounts you will obtain from each task from the items claimed overtime in the current BoQ (See claim 1 to 9). This must be calculated for each task.
- **Cost Variance** (CV) column. This equals EV –AC. This must be calculated for each task.
- **Schedule Variance** (SV) column. This equals EV –PV. This must be calculated for each task.
- **Cost Performance index** (CPI) column. This equal EV/AC. This must be calculated for each task.
- **Schedule Performance index** (SPI) column. This equal EV/PV. This must be calculated for each task.

From the above data you should also generate a cash flow chart which must show the estimated cost of each period (bars) and the accumulated cost (line). This can easily be calculated with the timeline and PV value.

Furthermore you must also generate overall **Earned Value Management** (EVM) Parameters chart which will show the accumulated PV value over time, AC value over time, EV over time.

The above can easily all be done in Excel; however, MS project has function to generate these reports automatically. Therefore for additional training (not required if software is not available) verify the above with MS projects programme.

Feedback from trainee was provided to the client electronically.

Evolution of Assignment 3 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment					X
2. Trainee’s Feedback					X
3. Brief Summarized Report					
4. Presentation					

Date

Signature Mentor

Assignment 4

Please download a student version of ANSYS onto your computer and complete the assignment below. Attached also please find all relevant information to complete the assignment.

1. Square Beam

a. Import the geometry Square_Beam.sat file into your project.
b. Fixed the beam on one side.
c. Apply a load of 10 000 N in the downwards direction on the other side.
d. Ignore the weight of the beam.
e. Solve the total deflection of the beam.
f. Solve the normal stresses in the beam.
g. With beam theory calculate the stress as well is the deflection of the beam by hand.
h. How do these compare to the results you obtained from the FEA?
i. Now increase the number of nodes by decreasing the element size to 0.02 m.
j. How many elements does the beam now have? Does this improve the answers you calculated from the first FEA?

2. Elevated Permeate Tank Stand

a. Import the geometry Tank_Stand.sat file into your project.
b. Make sure the structure elements are bonded.
c. Apply the load from the water tank (see attached drawing), the weight of the rectangular tubing (see attached drawing), as well of its own weight to the stand.
d. The load should be applied on top of the Channel beams.
e. Complete a FEA report (see example attached) on the structure.
f. Import the geometry Tank_Stand_A.sat file into a new project and repeat the above.
g. Is there significant difference in the results?

No feedback was provided by the trainee.

Evolution of Assignment 4 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment	X				
2. Trainee's Feedback	X				
3. Brief Summarized Report					
4. Presentation					

Date

Signature Mentor

ELECTRICAL AND ELECTRONIC

Assignment 1

1. Obtain annual hourly solar data for the two sites (Grünau and Bethanie) with regard to the direct normal irradiance (DNI), diffuse horizontal irradiance (DHI), and global horizontal irradiance (GHI).
2. Calculate the total irradiance on the photovoltaic (PV) module from the above, assuming 20° north facing fixed modules. Also take the temperature into account.

No feedback was provided by the trainee.

Evolution of Assignment 1 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment	X				
2. Trainee's Feedback	X				
3. Brief Summarized Report					
4. Presentation					

Date

Signature Mentor

Assignment 2

For each of the plant alternatives (see preliminary design report) size the number of PV panels required and the battery bank required. Take the following into account:

- Panel capacity for Grünau is 290 Wp (See attached information);
- Panel capacity for Bethanie is 310 Wp (See attached information);
- Please note that the PV modules capacity drops to 80 % through its lifetime (25 years). This must be considered when sizing the system;
- Also both sites have a little bit of dust and this should also be taken into account. At this stage assume a decrease of 5 % in the capacity due to the dust.

No feedback was provided by the trainee.

Evolution of Assignment 2 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment	X				
2. Trainee's Feedback	X				
3. Brief Summarized Report					
4. Presentation					

Date

Signature Mentor

Assignment 3

Please construct a spreadsheet (additional sheet) to reflect the current Gantt Chart of NEC (contractor).

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- **Schedule Variance** (SV) column. This equals EV –PV. This must be calculated for each task.
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No feedback was provided by the trainee.

Evolution of Assignment 3 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment	X				
2. Trainee's Feedback	X				
3. Brief Summarized Report					
4. Presentation					

Date Signature Mentor

CIVIL

Assignment 1

From the data contained in the inception design report calculate the size and number of ponds to ensure sufficient evaporation take place. Once the size has been calculated complete a preliminary bill of quantities to calculate the preliminary cost of excavation works.

No feedback was provided by the trainee.

Evolution of Assignment 1 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment	X				
2. Trainee's Feedback	X				
3. Brief Summarized Report					
4. Presentation					

Date

Signature Mentor

Assignment 2

From the data contained in the final design report and the discussions during the session calculate the optimal size and number of ponds for each site i.e. at Grünau and Bethanie.

No feedback was provided by the trainee.

Evolution of Assignment 2 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment	**X**				
2. Trainee's Feedback	**X**				
3. Brief Summarized Report					
4. Presentation					

Date

Signature Mentor

Assignment 3

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n. Ignore the weight of the beam.
o. Solve the total deflection of the beam.
p. Solve the normal stresses in the beam.
q. With beam theory calculate the stress as well is the deflection of the beam by hand.
r. How do these compare to the results you obtained from the FEA?
s. Now increase the number of nodes by decreasing the element size to 0.02 m.
t. How many elements does the beam now have? Does this improve the answers you calculated from the first FEA?

2. Elevated Permeate Tank Stand

h. Import the geometry Tank_Stand.sat file into your project.
i. Make sure the structure elements are bonded.
j. Apply the load from the water tank (see attached drawing), the weight of the rectangular tubing (see attached drawing), as well of its own weight to the stand.
k. The load should be applied on top of the Channel beams.
l. Complete a FEA report (see example attached) on the structure.
m. Import the geometry Tank_Stand_A.sat file into a new project and repeat the above.
n. Is there significant difference in the results?

No feedback was provided by the trainee.

Evolution of Assignment 3 by Mentor:

Description	Not Completed	Poor	Fair	Good	Excellent
1. Understanding of the Assignment	X				
2. Trainee's Feedback	X				
3. Brief Summarized Report					
4. Presentation					

-------------------------------- Date

-------------------------------- Signature Mentor