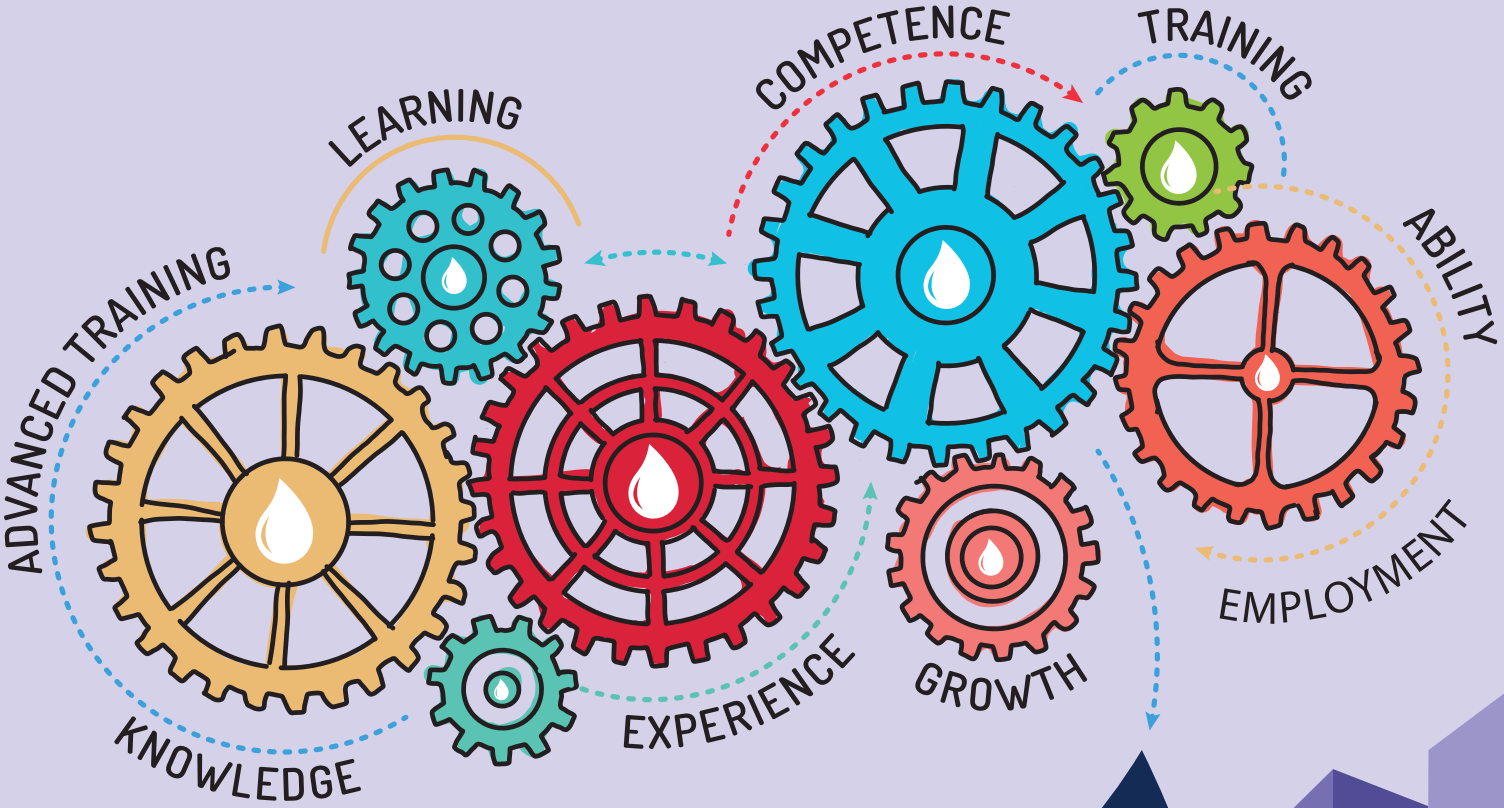
WATER RESEARCH DEVELOPMENT AND INNOVATION (RDI) ROADMAP SKILLS MAPPING STUDY

VOLUME IV: WATER SECTOR SKILLS DEMAND

Dr Michele Carstens, Chris Swartz, Dr Brandon Reyneke, Dr Monique Waso, Dr Elanna Bester and Manuel Jackson



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WATER RESEARCH DEVELOPMENT AND INNOVATION (RDI) ROADMAP SKILLS MAPPING STUDY

VOLUME IV: WATER SECTOR SKILLS DEMAND

Report to the
Water Research Commission

by

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The outputs of this research project are presented in four separate publications:

Volume I: Updated RDI Roadmap Capability Map **(WRC Report No. TT 865/1/21)**
Volume II: Water Sector Postgraduate Training Map **(WRC Report No. TT 865/2/21)**
Volume III: Short Course Skills Mapping Study **(WRC Report No. TT 865/3/21)**
Volume IV: Water Sector Skills Demand Report **(This report)**

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EXECUTIVE SUMMARY

Introduction and Context

The Water Research, Development and Innovation (RDI) Roadmap (2015-2025) is a high-level planning intervention that facilitates and guides the refocusing of research, reprioritisation of funds, synergising of existing initiatives and ring-fencing of new resources to facilitate a more optimal water innovation system. The Water Research Commission (WRC) Roadmap Implementation Unit introduced the finalised RDI Roadmap to relevant stakeholders in the water sector, including universities, water boards and utilities, municipalities, government organisations, entities and companies, during 2016 and 2017 through a series of national roadshows and workshops. During these sectoral engagements a set of human capacity and development needs and opportunities in the water sector emerged. This led to the objective of this study, namely understanding the skills demand in the water sector. The research impact of this report is to inform Higher Education Institutions (HEIs), the WRC, the Department of Higher Education and Training (DHET) and the Energy and Water Sector Education Training Authority (EWSETA) of the water sector demand, with both a current and future focus.

Methodology

The methodological process adopted for this study was based on the collection of quantitative data, through the distribution of an online questionnaire to Human Resources managers, skills development personnel, line managers, engineers and water-related researchers, and the collection of qualitative data through sectoral focus group interviews and semi-structured future skills interviews.

The online survey questionnaire investigated the skills demand for water-related occupations at a technical to a specialised level. In this study, occupations at technical to specialised levels were defined as skills requirements for employees with qualifications with National Qualifications Framework (NQF) levels 6 to 10. The scope of the questionnaire was further defined by including occupations requiring technical skills referring specifically to engineering and scientific skills. The South African Organising Framework for Occupations (OFO) was used to list all water-related occupations in the water sector (with the RDI environment being the only exception) based on the literature studied. Every occupational grouping (up to the 4th digit level) in the OFO has a list of associated tasks, considered the outputs of the respective occupation. This common set of tasks was used as basis for generating the skills sets the respondents had to complete for the skills matrices of the respective water-related occupations. Occupations, and their respective skills matrices, relevant to institutions and organisations involved in water-related RDI activities were constructed based on literature. Respondents were furthermore requested to indicate which occupations were vacant and/or experienced a high staff turnover rate as well as select the respective reasons.

Focus group interviews were held to collect data on the following themes: occupations and skills; graduate and postgraduate skills demand; and addressing skills gaps in the water sector. Stakeholders were identified and focus group interviews were held for each of the following sectors: agriculture; Catchment Management Agencies (CMAs); consulting/engineering; manufacturing; mining; municipalities; national or provincial government and water board or utility. Written inputs were provided for the water-related RDI environment.

A specific focus point for the skills demand study was also an estimation of future skills demand. Semi-structured interviews with identified key stakeholders were held to determine how the demand for skills could change in the future. Stakeholders were requested to indicate factors which they foresee will drive change in the water sector and how it could impact the future demand and supply of skills. Interviewees were also requested to make suggestions of how key organisations and institutions can prepare for future changes

through skills demand. Lastly, interviewees were requested how they foresee the COVID-19 pandemic will impact the water sector (e.g. infrastructure needs, working conditions of employees and skills deployment within organisations).

Results and Conclusions

The questionnaire, distributed to 445 stakeholders, had a response rate of 9.44%. Although the response rate was low, respondents of key organisations from the agricultural sector; CMAs; consultancy and engineering; RDI sector; industrial sector; mining; municipalities; national or provincial government; and water boards and utilities participated. However, no respondents from the manufacturing sector completed the questionnaire.

The questionnaire results indicated that the top ten skills in demand in the water sector are: “using large scale datasets (big data)”; “information management”; “Geographic Information Systems (GIS) and remote sensing”; “time management”; “understand the internal and external environment”; “training”; “risk management”; “participation in research and development”; “sampling and data collection”; and “supervision of staff”. Major skills gaps identified during the focus group interviews were related to skills obtained through practical/work experience and the lack of organisations’ capacity to mentor, train, teach and develop young professionals to bridge this gap.

In the water-related RDI environment the questionnaire results indicated that the top ten skills in demand are: “risk management”; “visioning”; “information management”; “new business development”; “social astuteness”; “understand the internal and external regulatory environment”; “dissemination and exploitation of research outcomes”; “networking ability”; and “understand the business environment in which the company operates”. The following skills are all at position ten: “commercial awareness”; “emotional intelligence”; “integration”; “leadership skills”; and “using large scale datasets”. Major skills gaps identified during the focus group interviews for the water-related RDI environment were related to the use of large scale datasets and the ability to take science to society. The lack of social sciences and socio-ecological-systems thinking within the water-related RDI environment was also noted.

All 45 OFO occupations included in the questionnaire were indicated as “vacant”, except for Local Authority Manager (Water Services Manager). Similarly, the questionnaire results indicate that the vacant option was selected for all the occupations in the water-related RDI environment. Reasons for the vacancies for the water-related occupations includes: “candidates not registered with professional body”; “economic climate”; “lack of experience”; “lack of qualifications”; “poor remuneration”; “slow recruitment process”; and “unsuitable job location”. Only seven occupations had “new or emerging job” listed as one of the reasons for a vacancy while no occupations had “unsuitable working hours” listed as a reason. In contrast, in the water-related RDI environment respondents were more selective, with between one to three reasons listed as reasons for vacancies for each respective occupation. For the RDI component of the study none of the respondents selected the reasons: “candidates are not registered with professional body”; “unsuitable job location”; and “unsuitable working hours” as reasons for vacancies.

During the semi-structured focus group interviews, current vacancies were recorded for engineers, hydrologists and geohydrologists. Reasons for the respective vacancies were noted by the interviewees to include, amongst others, relocation to cities, better career opportunities and remuneration, lack of relevant work experience, lack of relevant qualifications, lack of registration with a professional body, and late submissions of applicants.

Of the 45 OFO occupations included in the questionnaire, the high staff turnover rate option was selected for all the occupations except for Local Authority Manager (Water Services Manager). Similarly, the high staff turnover rate option was selected for all the occupations in the water-related RDI environment. Results from the questionnaire indicated that the high staff turnover rate for the occupations within the water sector, as reported by the respondents of the respective organisations, are: “contract closure”, “dismissals”, “economic

climate", "resignations" and "retirement". In contrast, the reasons for high staff turnover rates for occupations within the water-related RDI environment, as reported by the respondents of the respective organisations and institutions, are: "contract closure", "resignations" and to a lesser extent the "economic climate".

During the focus group interviews, high staff turnover rates were reported for local, provincial and national government mainly due to the fact that employees move to the private sector or between the different types of municipalities (local, district and metropolitan municipalities) able to offer more competitive remuneration packages.

Results from the questionnaire indicated that all the listed learning interventions are applied to reskill and/or upskill all the occupations in the water sector and the occupations within the water-related RDI environment. The only exception was technology transfer officer as none of the respondents selected the occupation as filled within their organisation. "Formal qualification", "professional registration and Continuous Professional Development (CPD)", "short courses" and "workplace learning" (mentoring system) were selected as learning interventions for all the occupations included in the study.

During the focus group interviews, short courses, training programmes, conferences, and using outsourcing and contracting as a tool for knowledge transfer were identified as learning interventions currently employed by the interviewees' organisations. Although the interviewees acknowledged the opportunity for employees to attend short courses to reskill and upskill themselves, barriers such as budget constraints, commitment issues due to no monetary gain for attending learning interventions, division of work while certain employees are on training, lack of management of training of personnel, and lack of government-approved service providers were reported. Professional registration was also noted as an important criterion for employment in certain sectors, while the importance of workplace learning (mentoring system) was also noted.

It was observed that most of the organisations that form part of the water sector employ Honours and Master's graduates, with Doctoral graduates less frequently employed as these professionals tend to go into research specific fields.

During compilation of the literature review for the future skills component, it was identified that factors such as data and analytics, leadership, the customer, delivery models, (contracting, outsourcing, insourcing), entrepreneurship (innovation), and collaborations (partnerships with other sectors) will drive and facilitate change in the future water sector and will influence the future skills required within the water sector. It was confirmed during the future skills semi-structured interviews that all of these factors play and will play an important role in the future water sector of South Africa. However, it was also stressed that additional factors may play a role in the South African context. The sector needs to adapt to the "new normal" and to implement more permanent solutions to the ever increasing water-related challenges faced by South Africa. This will also require innovators and leaders that can design these permanent solutions and ensure that they are adequately implemented. Furthermore, this will require a more transdisciplinary approach which will not only consider engineers but will also require the inputs from health care professionals, health scientists, social scientists, natural scientists, economists and many more occupations and professionals. Thus, a greater diversity of professionals and occupations within the water sector workforce and by extension a greater set of diverse skills will be required in the future water sector of South Africa.

The COVID-19 pandemic has impacted skills development negatively in the water sector due to the cancellation of certain training and networking opportunities. However, strategies applied by different organisations to continue with learning and skills development using online platforms (i.e. hybrid learning at HEIs and offering of online short courses, training programmes and conferences) during the pandemic could increase accessibility to individuals and should be further investigated in long term skills planning of the water sector.

Overall conclusions and high level strategic findings

The main objective of the RDI Roadmap is to support high-end human capacity development for water research, development and innovation. The main areas of support as studied in this project concerned RDI capability mapping (Volume 1); post-graduate level skills mapping, specifically mapping water-related postgraduate courses (Volume 2); and mapping of short courses offered to the water sector (Volume 3). High level findings from these studies are summarised and integrated below (refer to Chapter 8 of the report).

- The objective of the capability mapping was to establish where the different water-related RDI disciplinary skills are located in the country. It also provides information on the different competencies, which allows for a more focused consideration on how to best support and structure the RDI capability optimally.
- For most of the RDI Roadmap clusters used in the study, there seems to be an alignment between the total investment required in the Roadmap (2015-2025) and the reported water-related RDI activities. The figures on the investment requirements are, however, based on forecasts. Due care should therefore be taken when using the investment requirements as stated in the Water RDI Roadmap as an indicator.
- The research conducted for the Water RDI Roadmap took place from 2014 to 2015. The water-related RDI landscape in South Africa could have changed during the last few years and is an area for future research.
- An additional component of this research focused on the research strength based on bibliometric data (2014-2018) using the total number of different outputs (articles, proceedings papers, reviews, book chapters) as well as average number of citations per item. For a number of institutions where the research maturity during the RDI Capability Mapping Study was rated as emerging, less than 50 publications were produced by these institutions. For institutions that produced high levels of research publications between 2014 and 2018, the results are comparable to some HEIs with certain RFAs identified with levels of RDI activity rated as “matured”.
- The main objective of the post-graduate study was to develop a detailed map of the current water sector-related postgraduate training (Honours, Master’s, PhD) offered at all 27 HEIs in South Africa. From this mapping it was then possible to identify gaps in post-graduate offerings.
- The anticipated RDI outcomes for human capital development in the Water RDI Roadmap (2015) are 215 post-doctoral researchers, 537 doctorates and 805 masters, based on a set of productivity assumptions. The current postgraduate study indicated that these anticipated postgraduates can select a water-related postgraduate programme from a comprehensive list of options (107 general degrees and 55 specialised postgraduate degree programmes). Furthermore, the range of HEIs from which postgraduate students could select from to obtain their degrees is also comprehensive with 21 of the 27 HEIs offering water-related postgraduate programmes.
- Analysis of the focus group interviews led to important findings regarding the level of support for postgraduates which could influence the anticipated human capital development outcomes of the Water RDI Roadmap. These findings included:
  - ⇒ A lack of a consistent funding source for the water industry was noted by interviewees as a deterrent for postgraduate enrolments. Interviewees also noted that the restructuring of the National Research Foundation (NRF) over the last 2 years, for instance, has affected the availability of funding for many students wanting to enrol for postgraduate research.
  - ⇒ A lack of depth or succession plans, noted during the interviews, should academic staff leave academia is also challenge which could impact human capital development negatively. This is in alignment with DST (2017) where it is noted that while postgraduate enrolment rates have increased, there has been no corresponding increase in the number of academic staff.
- To address this, it is recommended that in future the supply of postgraduates graduating with a water-related degree could be investigated by monitoring the number of postgraduates obtaining degrees

from all the water-related postgraduate programmes identified in this study. The information obtained could then be compared to the targets included in the Water RDI Roadmap for further evaluation.

- However the following preliminary and exploratory scenarios are described to investigate whether the identified water-related postgraduate programmes will provide sufficient support for the Water RDI Roadmap to reach its postgraduate targets using the number of postgraduates as basis:
  - ⇒ The Water RDI Roadmap has a target for 537 doctorates during a ten year period (2015-2025). The study identified 14 specialised and 91 general doctoral programmes. Therefore to reach the target in the ten year period, for example, each general doctoral programme should have five successful candidates obtaining their general degrees with a focus on water and each specialised doctoral programme should have six successful candidates obtaining their specialised degree. However if every general doctoral programme has four successful candidates obtaining their degrees with a focus on water, it means that each specialised degree must then have 13 successful candidates during the ten year period.
  - ⇒ This study also identified strategic and operational gaps in the current water sector-related postgraduate training (Honours, Master's, and PhDs). By addressing these gaps and investigating the recommendations included in this study, the level of postgraduate support could be improved to assist the Water RDI Roadmap with reaching its postgraduate targets.
- From a supply perspective, the postgraduate mapping study identified water-related postgraduate programmes offered by HEIs in South Africa but did not monitor the number of individuals graduating from these respective programmes (current supply of postgraduates). Similarly, the aim of the demand side skills study was to investigate what specific skills the water sector requires, and not specifically the number of postgraduates the water sector absorbs. However, most of the organisations in the water sector employ doctoral graduates less frequently as these professionals tend to go into research specific fields. Therefore, if it is envisioned that a percentage of the postgraduate targets in the Water RDI Roadmap should be employed within the wider water sector, it is a possible concern and should be further investigated. Furthermore, the National Development Plan of 2030 aims to significantly increase the number of PhD graduates in South Africa and aims to make this qualification more desirable for prospective graduates. This also prompts the need for future research in the employment prospects of PhDs with a water-related degree in the private sector as well as more permanent positions in academia.
- Results from this study indicate that short courses in the water-related RDI environment could serve as a powerful tool of knowledge transfer and the inclusion of targets for short courses in the Water RDI Roadmap should be considered (targets for RDI-relevant water-related short courses were not present in the Water RDI Roadmap of 2015). This recommendation is made since 134 RDI-relevant water-related short courses have already been identified in this study. As these courses are offered by HEIs (54%), professional bodies (28%) and research and innovation specialists (19%) it is assumed that the short course facilitators have the required expertise to present the content of the respective short courses.
- The study has identified operational and strategic gaps in the available RDI-relevant water-related short courses. By addressing these gaps and investigating the recommendations included in this study, the effectiveness and sustainability of using short courses as a tool of knowledge transfer in the water-related RDI environment can be improved.
- Data from the water-related RDI capability mapping, postgraduate mapping and short course mapping studies were compiled to draw a comparison between the different Roadmap clusters (Table 16 in Chapter 8 of this report).

Recommendations

The following recommendations are made to address skills gaps in the water sector, based on the qualitative findings of the study:

- To train and mentor graduates and young professionals
- To mentor and train employees within organisations
- To incorporate practical and work experience components into training courses and degrees

- Integrate the development of soft skills and leadership skills into training
- To continue with the learning interventions: short courses, training programmes and conferences
- To use contracting and outsourcing, where feasible and applicable, as a tool for knowledge transfer
- To foster and build collaboration between organisations
- To foster and build collaboration between HEIs and organisations
- To develop entrepreneurial skills within the water sector, especially the RDI environment
- Construct and create “urban living laboratories” where Research and Development (R&D) projects can be piloted and skills can be transferred between individuals
- Develop multi-disciplinary talent within the RDI environment
- To continue to use, where the need arises, online platforms (or hybrid systems) for short courses and conferences even after the COVID-19 pandemic
- To continue to use, where the need arises, hybrid/blended learning systems even after the COVID-19 pandemic.

Lastly, data from the water-related RDI capability mapping, postgraduate mapping and short course mapping studies were compiled to draw a comparison between the different clusters and also to compare the data to the WRC RDI Roadmap (2015-2025). General observations were made when comparing the results of the skills demand study and the studies conducted on the supply side.

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ACRONYMS and ABBREVIATIONS

ACEWater	African Centres of Excellence Human Capacity Development Programme
ARC	Agricultural Research Council
ATR	Annual Training Report
CMA	Catchment Management Agencies
COGTA	Department of Cooperative Governance and Traditional Affairs
CPD	Continuous Professional Development
CPUT	Cape Peninsula University of Technology
CSIR	Council for Scientific and Industrial Research
CUT	Central University of Technology
DEA&DP	Department of Environment Affairs and Development Planning
DHET	Department of Higher Education and Training
DIRCO	Department of International Relations and Cooperation
DSI	Department of Science and Innovation
DUT	Durban University of Technology
DWS	Department of Water and Sanitation
ECSA	Engineering Council of South Africa
EWSETA	Energy and Water Sector Education Training Authority
GIS	Geographic Information Systems
HEI	Higher Education Institution
HTFV	Hard To Fill Vacancy
IIE MSA	Independent Institute of Education Monash SA
IMESA	Institute of Municipal Engineering of Southern Africa
IOPSA	Institute of Plumbers South Africa
iWETS	Improving Water Education and Training Skills in SA
LGSETA	Local Government Sector Education and Training Authority
LMIP	Labour Market Intelligence Partnership
LU	Limpopo University
MUT	Mangosuthu University of Technology

NDP	National Development Plan
NMMU	Nelson Mandela Metropolitan University
NQF	National Qualifications Framework
NSTF	National Science and Technology Forum
NWRS	National Water Resource Strategy
NW&SMP	National Water and Sanitation Master Plan
NWU	North West University
OFO	Organising Framework for Occupations
OIHD	Occupations in High Demand
PB	Professional Body
PIVOTAL	Professional, Vocational, Technical and Academic Learning
QC	Quality Council
R&D	Research and Development
RDI	Research Development and Innovation
RFA	Research Focus Area
RU	Rhodes University
SAAE	South African Academy of Engineering
SALGA	South Africa Local Government Association
SANBI	South African National Biodiversity Institute
SANWATCE	Southern African Network of Water Centres of Excellence
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SETA	Sector Education and Training Authority
SMME	Small Medium and Micro Enterprise
SMU	Sefako Makgatho Health Sciences University
SPOL	Sectoral Priority Occupations and Interventions List
SPU	Sol Plaatje University
SSP	Sector Skills Plan
SU	Stellenbosch University
TCTA	Trans Caledon Tunnel Authority
TUT	Tshwane University of Technology

TVET	Technical and Vocational Education and Training
UCT	University of Cape Town
UFH	University of Fort Hare
UFS	University of the Free State
UJ	University of Johannesburg
UKZN	University of KwaZulu-Natal
UMP	University of Mpumalanga
UNISA	University of South Africa
UNIVEN	University of Venda
UNIZULU	University of Zululand
UP	University of Pretoria
UWC	University of the Western Cape
VUT	Vaal University of Technology
WB	Water Board
WE&RF	Water Environment & Reuse Foundation
WISA	Water Institute of Southern Africa
WITS	University of the Witwatersrand
WRC	Water Research Commission
WSA	Water Service Authority
WSAA	Water Services Association of Australia
WSLG	Water Sector Leadership Group
WSP	Workplace Skills Plan
WSP	Water Service Provider
WSU	Walter Sisulu University
4IR	Fourth Industrial Revolution

CHAPTER 1: INTRODUCTION AND CONTEXT

The Water Research Commission (WRC) Water Research, Development and Innovation (RDI) Roadmap (2015-2025) is a high-level planning intervention that facilitates and guides refocusing of research, reprioritisation of funds, synergising of existing initiatives and ring-fencing of new resources to facilitate a more optimal water innovation system. The WRC Roadmap Implementation Unit introduced the finalised RDI roadmap to relevant stakeholders in the water sector, including universities, utilities, municipalities, government organisations, entities and companies, during 2016 and 2017 through a series of national roadshows and workshops. During these sectoral engagements a set of human capacity and development needs and opportunities in the water sector emerged (WRC, 2017). This led to this study namely the Water RDI Roadmap Skills Mapping Study.

As there is a limited understanding of the market demand for specific skills in the water sector, the objective of the demand side skills study is to understand the water sector skills demand better. This is despite the presence of numerous water sector skills development initiatives across South Africa. This in turn raises concerns about what students are being trained for, what the sectoral needs are, and what the employment opportunities will be for graduates once they have completed their studies. There is also a lack of clarity about how employees in existing posts need to be upskilled or reskilled in preparation for changing needs and dynamics in the water sector and work place. Interactions with universities have made it clear that there is a range of water sector relevant postgraduate training offerings available; some of these postgraduate courses have a specific water niche/focus whilst many have a more general disciplinary focus.

The South African Organising Framework for Occupations (OFO) is used by the Department of Higher Education and Training (DHET) to monitor skills demand and supply, as well as the Sector Education and Training Authorities (SETAs) and employers to collect information for respective sector and workplace skills plans. Not only does the use of the OFO across the SETAs and DHET ensure more consistent reporting and monitoring but it also provides the opportunity to identify trends across different sub-sectors and economic sectors for the development of strategies to address similar skill shortages (OFO, 2013). The benefits of using the occupational profiles with their curricula and assessment specifications in the OFO by industry, include more consistent job descriptions and performance assessment processes. Another benefit for industry using the OFO is a more consistent naming convention when advertising posts and generating legislated reports. The occupational tasks in the OFO can also be linked to occupational qualification development and assessment. Lastly, occupational groupings can be linked to occupational pathways which are used to inform career management in the workplace (OFO, 2013). Therefore the current study uses the occupations and specialisations and their associated tasks in the OFO (2019) as basis for the skills demand study in the water sector.

A specific focus point for the skills demand study is also an estimation of future skills demand, based on a forecast considering the situation locally. Skills requirements in the future could change due to a number of factors in the water sector. The Energy and Water Sector Education Training Authority's Sector Skills Plan (EWSETA SSP) lists a number of major factors affecting skills demand and supply including: technology and the Fourth Industrial Revolution (4IR) change drivers; water scarcity change drivers; political, government, economic, and regulatory change drivers; infrastructural change drivers; industry/market change drivers; and business/organisational-level change drivers (EWSETA, 2019).

The research impact of the skills demand side study is to inform organisations involved in skills planning and supply which include higher education institutions (HEIs), the WRC, DHET, the Department of

Science and Innovation (DSI), Local Government Sector Education Training Authority (LGSETA), and EWSETA of the water sector demand, with both a current and future focus. The information in this report will also inform current and prospective graduate and postgraduate students on the demand for water sector relevant skills.

CHAPTER 2: LITERATURE REVIEW

2.1 POLICIES PERTAINING TO TRAINING AND SKILLS DEVELOPMENT IN THE WATER SECTOR

2.1.1 Department of Water and Sanitation

The National Water Act of 1998 requires the formulation of a National Water Resource Strategy (NWRS), to be reviewed at 5-year intervals. The second edition of the NWRS of 2013 (NWRS2) outlines DWS (Department of Water and Sanitation) strategies to ensure '*Sustainable, equitable and secure water for a better life and environment for all'*. The aim of the NWRS2 is to give effect to the NDP's 2030 Vision by aligning its strategies with the goals of that of the NDP. This is essential since water provisioning and protection plays a crucial role in numerous sectors, including industry, energy, agriculture, mining, tourism, urban growth and rural development.

One of the goals of the NWRS2 is to *'Develop capacity and skills to address all elements of water resource functions (protection, development, conservation, management and control)'*. The alignment of the NWRS2 with the NDP, as it relates to skills development, training and graduate recruitment in the water sector is summarised in Table 1.

Table 1: A summary of the areas where skills development, training and graduate recruitment in the water sector aligns with the aims of the NDP Vision 2030 for South Africa (NWRS2, 2013)

Areas	NDP Target or Action	Water Sector Programme
Economy and employment	Creation of 11 million jobs by 2030	Recruitment programmes for • Scientists • Technicians • Engineers • Managers • Development practitioners
Education and innovation	• Improve skills planning strategies • Shape skills production • Develop a suite of qualifications of excellent quality • Develop support for non-formal programmes	• DWS Learning Academy • Development of Water Sector Skills Strategy to improve skills planning and the production of sector-relevant skills
Building a capable state	• Formalised scheme for the recruitment of graduates for public service • Skills strategies for managers, technical, professional and local government staff	• DWS Learning Academy • Mentorship programmes • Occupational specific dispensation posts

The DWS Learning Academy or Career Management Programme builds capacity by working to secure the supply of high-level skills in science, engineering and management. The programme offers bursaries to under- and postgraduate students enrolled in designated fields of study at Technical Universities or Universities. The fields of study considered for funding are based on an annual DWS needs analysis and successful graduates are required to join the Water Learning Academy as Trainees

on a fixed term contract for a maximum of 3 years. During this period, graduate trainees are mentored by providing on-the-job and specialised training to enable them to register with a professional body (PB) (where applicable).

Chapter 15 of the NWRS2 details the current limitations related to education, training and skills development in the sector and proposes corresponding remedial strategies (Table 2).

Table 2: Various issues of strategic importance to education, training and skills development and the proposed response as outlined in the NWRS2 (2013)

Problems related to education, training and skills development in the Water Sector	Strategic action and specific objectives proposed
• **No coordinated mechanism to plan, deliver and assure the quality of programmes intending to build capacity, train and develop skills** • **Multiple institutions and providers in the sector facilitating education, training and skills development** • **Lack of capacity amongst institutions and providers to deliver qualifications that meet the Sector's needs** • **Education, training and skills development are governed by a complex regulatory system [National Qualifications Framework (NQF), sub-frameworks and the Quality Councils (QCs)]** • **Uncoordinated funding mechanisms drive education, training and skills development leading to overlaps, or gaps in critical areas** • **A significant time lapse between obtaining a higher education qualification and professional registration (between 3 to 5 years)** • **Absence of a sector skills intelligence hub** • **Poor human resource planning in the sector (i.e. no succession planning, weak retention strategies and insufficient induction of professional entrants)** • **No Water Occupations Framework guiding planning and classification of occupations**	The overarching strategic objective is to implement a well-coordinated and coherent system for capacity building in the Water Sector. This will be achieved by the following objectives: • Cement the strategic position of the EWSETA and Local Government Sector Education and Training Authority (LGSETA) within the sector to enable these bodies to coordinate demand-driven skills planning for short-, medium- and long-term sector requirements • Strengthen good water governance practice in all water institutions by building management capacity • Reinforce the mechanisms which the DWS uses to provide strategic leadership in sector training and capacity building • Establish a model to effectively coordinate institutional capacity building in the sector • Develop a strategy for the professionalization of institutions and practitioners as well as on-going development programmes, including mentoring, coaching, seminars and short courses • Develop a sector skills intelligence facility, which places an emphasis on present and future skills needs • Strengthen the relationships between all stakeholders in the skills development pipeline (education institutions, workplaces, local and international providers) • Striking a balance between the need for informal and formal short-term initiatives (on-the-job training, mentoring, coaching) and formalised, long-term organisational training programmes • Identification of under-utilised capacity in the sector, followed by engagement and development (i.e. recognition of prior learning or tracing past graduates)

The National Water and Sanitation Master Plan (NW&SMP): Call to Action of 2018 outlines the actions, with designated responsible parties and timeframes, required to implement the strategies / policies contained in the NWRS2 (DWS, 2018). The NW&SMP clearly states that the implementation of the Plan '*requires the right mix of skills and expertise in the water sector. This includes the capacity expressed as number of persons and skills expressed by qualification and experience required to fulfil the requirements in water resources and water services planning, management and operations. A critical need is to use the expertise of experienced water managers to mentor and develop younger and less experienced managers in the water sector including, but not limited to, the municipal sector.'* The

NW&SMP outlines five capacity-building actions, along with the responsible parties and a completion date (Table 3).

Table 3: The five capacity-building actions, with designated responsible parties and expected completion date, outlined by the NW&SMP (DWS)

Action	Responsible parties	Completion date
Develop and implement a qualification for municipal water managers. **Topics covered during 18 months are asset management, tariffs and revenue management, drought management, stakeholder engagement and customer relations.** **The EWSETA-accredited qualification will be mandatory, modular and practical.**	DWS, EWSETA	First course piloted in 2020/21
Establish regulations stipulating the prerequisite qualifications and experience required for senior and technical positions in the DWS, catchment management agencies (CMAs), water boards (WBs) and municipal water services.	DWS, Department of Cooperative Governance and Traditional Affairs (COGTA)	2020
Develop and implement a programme to recruit and retain experienced technical and managerial staff with technical qualifications (national and international recruitment).	DWS, COGTA, Department of International Relations and Cooperation (DIRCO)	2020
Reinstate or outline career paths with defined training and on-the-job experience to build a cohort of professionals in the sector.	DWS, Water Services Authorities (WSAs), WBs, Catchment Management Agencies (CMAs)	2019
Improve institutional capacity for investment in ecological infrastructure	DWS, Department of Environmental Affairs and Development Planning (DEA&DP), South African National Biodiversity Institute (SANBI)	2022

2.2 SKILLS DEMAND IN THE WATER SECTOR

Below is a review of publically available literature outlining the demand for skills in the sector. Also included are examples of methods previously used to determine gaps between the demand and supply of skills in the general labour market as well as the water sector.

2.2.1 EWSETA – Energy and Water Sector Education and Training Authority

The EWSETA is mandated to analyse the skills demand, skill level requirements and skills supply in the energy and water sectors. The scope of EWSETA is described by the Standard Industrial Classification (SIC) codes. The industries relevant to the water sector covered by EWSETA are the following: collection, purification and distribution of water (SIC 42000); public water enterprises (collection, purification and distribution of water, including potable water supply, domestic waste and sewage services, refuse and sanitation services) (SIC 42001); private water companies (collection, purification and distribution of water, including potable water supply, domestic waste and sewage

services, refuse and sanitation services) (SIC 42002); irrigation boards (collection, purification and distribution of water, including potable water supply, domestic waste and sewage services, refuse and sanitation services) and water and sanitation services (potable water supply, domestic wastewater and sewage systems) (94003/99908) (EWSETA, 2019).

Their mandate extends to developing strategies to supply scarce and critical skills to the sectors and coordinating the implementation of training and education activities to achieve this goal. The EWSETA therefore coordinates its activities with public universities, Technical and Vocational Education and Training (TVET) Colleges, employers and industry experts to develop and implement occupationally directed programmes that address skills needs.

Individuals working in the water sector may require multiple skills to operate in various domains, including water management, ecology, water and wastewater treatment and management; often these skills have been developed 'on the job' rather than formal education/training programs. To address this gap, workplace learning, internships, candidacy programmes as well as mentoring initiatives are proposed to build skills capacity of graduates, in addition to developing formal training programs, and granting professional status to new occupations (EWSETA, 2018a).

The latest version of the EWSETA Sector Skills Plan (SSP) (EWSETA, 2019) for implementation from 2020-2025 was prepared according to the new DHET guidelines and is based on both quantitative and qualitative methodologies. For the EWSETA Baseline Impact Study primary quantitative data was obtained from two electronic employer surveys, collecting outcomes-related data and data on (Hard-To-Fill-Vacancies) HTFVs, respectively. Additional data sets were analysed from StatsSA, National Treasury and Trading Economics. Primary qualitative information for the Baseline Impact Study was acquired during in-depth face-to-face/telephonic interviews. During the SSP Desktop Research Study additional secondary data sets from various sources were analysed (EWSETA, 2019).

The EWSETA SSP contains a list of the top 10 priority occupations, collectively referred to as the Sectoral Priority Occupations and Interventions List (SPOL) as well as the top 20 Hard-To-Fill-Vacancies (HTFVs). Water-related occupations requiring technical skills, referring specifically to engineering and scientific skills, included in the HTFV list are Electrician (2017-671101), Electrical Engineer (2017-215101), Electronics Engineering Technologist (2017-215202), Civil Engineer (2017-214201), Water Process Controller (2017-313203), Electrical Engineering Technologist (2017-215102), Electronics Engineer (2017-215201), Industrial Engineering Technician (2017-311905), Civil Engineering Technician (2017-311201). The EWSETA SSP states the top three reasons for HTFVs are "lack of relevant experience"; "lack of relevant qualifications" and "new/emerging job/occupation in the sector". The most common skills gaps reported for senior level employees were "management and leadership skills", "project management skills" for mid-level employees and "technical/job-specific skills" for lower-level employees.

The SPOL was previously known as the Professional, Vocational, Technical and Academic Learning (PIVOTAL) programmes (EWSETA, 2019). The SPOL is an important deliverable for the SETAs since 80% of the discretionary budget is spent on this list and it is used to compile the DHET's list of Occupations In High Demand (OIHD). Water-related occupations requiring technical skills, referring specifically to engineering and scientific skills, included in the SPOL list are Environmental Engineer (2017-214301), Electrician (2017-671101), Civil Engineer (2017-214201), Water Process Controller (2017-313203) and Electrical Engineering Technologist (2017-215102).
Drivers of change in the water sector which could affect skills demand and supply included in the EWSETA SPP (2019) are the following: technology and the Fourth Industrial Revolution (41IR) change drivers; water scarcity change drivers (i.e. desalination, water and sanitation standards support

programme, innovation in water and sanitation, innovation in water and sanitation); renewable energy and solar power change drivers; political, government, economic, and regulatory change drivers (political arena, economic domain and entrepreneurship, regulatory and legal environment); infrastructural change drivers (strategic integrated projects, water infrastructure, energy infrastructure); industry/market change drivers; business/organisational-level change drivers. The New Industrial Policy Action Plan, the National Infrastructure Plan, the National Skills Development Plan and the Integrated Resource Plan have been identified in the EWSETA SSP (2019) as national plans and strategies which could have an impact on skills demand and supply.

Lastly, EWSETA has identified seven strategic skills priority actions to follow for achieving their mandate of meeting the current and future skills demand of the energy and water sector by developing and training learners. The strategic skills priority actions include: the implementation and coordination of research focusing on the labour market demand in the sector; the development of partnerships which will bring stakeholders together in the sector for the planning and implementation of imperatives to meet current and future skill needs; continued implementation of Recognition of Prior Learning (RPL) programmes; increased effort on Small Medium and Micro Enterprise (SMME) development, continued support for equity imperatives; establishment of a formal EWSETA monitoring and evaluation framework and implementing measures for supporting National Strategies and Plans (EWSETA, 2019).

2.2.2 LGSETA – Local Government Sector Education and Training Authority

The LGSETA plays a key role in ensuring that local government or municipal employees receive the necessary education and training to fulfil their job requirements and likewise published a SSP for 2020/21-2024/25 (LGSETA, 2020) containing a list of occupational shortages and the SPOL. The scope of LGSETA is also described by the SIC codes and the following are relevant to the water sector: any utility or agency, wholly or partially owned by a municipality, providing LG services (SIC 50493); municipal public works functions (specially designed) (SIC 88218); all functions, services and facilities provided by a metropolitan council (91201); all functions, services and facilities provided by local council (91202) and all functions, services and facilities provided by a district council and district area management (91203) (LGSETA, 2020).

The analysis of skills demand is based on data obtained from Workplace Skills Plan/Annual Training Report (WSP/ATR) submissions (2016-2019) and validated through stakeholder workshops.

Technical water-related occupations listed as occupational shortages (also referred to as scarce skills) include Electrician (2017-671101), Civil Engineer (2017-214201), Civil Engineering Technologist (2017-311201), Electrical Engineering Technician (2017-311301), Electrical Engineering Technologist (2017-215102), Civil Engineering Technologist (2017-214202) and Electrical Engineer (2017-215101). Water Reticulation Practitioner (2017-642601) and Water Quality Analyst (2017-213306) were included as two occupational shortages in the water services department. Furthermore the LGSETA SSP raises concerns that the number of learners qualifying as Water Reticulation Practitioners and Water Quality Analysts are decreasing which could add to the current crisis of the ailing maintenance of the country's water infrastructure. The top three reasons for occupational shortages included "recruitment process", "relevant qualification" and "financial".
Water-related occupations requiring technical skills, referring specifically to engineering and scientific skills, included in the SPOL list are Water Reticulation Practitioner (2017-642601), Civil Engineering Technician (2017-311201) and Electrical Engineering Technician (2017-311301).

Drivers of change in the local government which could affect skills demand and supply include: political change; spatial integration and inclusive development (urban and rural), local economic development,

constraints to service delivery (urban and rural) and technological change and digitisation. However the SSP states that the impact of these factors on skills demand and supply will remain theoretical unless there are policies in place which define the mandate of the local government accordingly. Although clean energy, for example, has skills implications for local government, these implications will remain theoretical until there is a policy which defines the mandate of the local government in this regard (LGSETA, 2020). To conclude, the SSP (LGSETA, 2020) has planned interventions to support the National Strategy and furthermore has prioritised skills in management, planning and technical occupations.

2.2.3 DHET – National List of Occupations in High Demand

The DHET publishes an updated National list of priority occupations (OIHD) every 2 years, with the latest version gazetted in 2018 (DHET, 2018). Currently a preliminary list of OIHD is available for public comment (DHET, 2020). The purpose of this publication is to guide and align education and training provision with the needs of the economy and wider governmental objectives.

The purpose of this publication is to guide and align education and training provision with the needs of the economy and wider governmental objectives. These OIHD are defined as those occupations that

1. show relatively strong employment growth (past and future)
2. are experiencing shortages in the labour market
3. are expected to be in demand in future (new or emerging occupations).

This definition combines past, present and anticipated occupational growth trends and it is possible that one or more of these factors can contribute simultaneously to an occupation being in high demand.

The South African OFO is used by the DHET to monitor skills demand and supply, as well as the SETAs and employers to collect information for respective sector skills plans and workplace skills plans. Quantitative and qualitative methodologies are used to compile the list and the occupations are ranked in demand (high, higher and highest) according to statistical analysis. The national OIHD (2018) with potential relevance to the Water Sector included: Electrical Engineering Technician (311301); Civil Engineering Technician (311201); Water Process Controller (313205); Mechanical Engineering Technician (311501); Project Manager (Technical) (121905); Engineering Manager (132104); Civil Engineer (214201); Mechanical Engineering Technologist (214402); Environmental Engineer (214301); Water Plant Operator (313201) and Civil Engineering Technologist (214202).

2.2.4 LMIP – Labour Market Intelligence Partnership

A 2018 technical report on OIHD in the general labour market published by the Labour Market Intelligence Partnership (LMIP, a collaboration between the Human Sciences Research Council and the DHET) notes that it is difficult to quantify OIHD. For this reason, most attempts at quantifying OIHD only measure existing skills shortages and furthermore measure indirect proxies, rather than skills in and of itself (e.g. educational qualifications, years of education, occupational classification, or earnings). All of these proxies have strengths and limitations regarding their usefulness and therefore the use of multiple proxies in combination is recommended to provide a more accurate indication of skills shortage (LMIP, 2018). The technical report contains a literature review of local and international studies into occupational shortages in SA.

The Technical Report reviewed two international approaches to determining skills and occupational needs and based its 2018 OIHD methodology on elements of these: the Shortage occupation lists

produced by the United Kingdom's Migration Advisory Committee and the Organisation of Economic Co-operation and Development's Skills for Jobs Indicators. In brief, the methodology used to compile the 2018 list of OIHD involved statistical (quantitative) as well as qualitative indicators.

The statistical (quantitative) methodology involved three components; identifying four dimensions of occupational demand, ten indicators and their associated thresholds.

The four dimensions of occupational demand used:

1. Wage pressure – increasing wages over time which are indicative of a current or future OIHD
2. Vacancy pressure – the duration of vacancy over time may be indicative of occupational shortages
3. Employment pressure – combined growth, intensity and turnover in employment
4. Priority or strategic demand – governmental policy or sectoral strategic plans may influence demand, and provide potential indication of future skills demand.

For the first three dimensions, measurement should be based on change relative to a period of time: i.e. occupational changes relative to median changes over a period for which a large amount of data is available. The fourth dimension, priority or strategic demand can only be based on recent data related to current policy or strategy.

Various indicators, which are used to measure/quantify each dimension were identified and the quality, compatibility and representivity of the available data were verified prior to its inclusion. The indicator thresholds identified a shortage as occurring when occupational changes greater than the median plus 50% were obtained. All of the data sources utilised in this report specified occupations at the 4-digit level of the OFO, and since the purpose of identifying OIHD is to guide training / skills development, only those occupations associated with a NQF level of 3 or greater, were included in the analysis. Six data sources were used, namely Quarterly Labour Force Survey, Labour Market Dynamics Study, Job Opportunity Index, Career Junction, SETA Pivotal Lists, and Strategic Integrated Projects List. The data for the various occupations were aggregated based on a mathematical formula involving the number of indicators in which an occupation exceeds its threshold and yielded a final result of 143 occupations with demand reflected in more than 25% of its weighted indicators. These occupations were grouped into 3 categories (high, higher and highest) using mean clustering analysis.

The qualitative component of the methodology extended the analysis from the 4-digit Unit Group Level of the OFO to the 6-digit Occupational Level and involved final verification whether each Occupation warrants being on the final list of OIHD, or not. Various sources of information were utilised to inform this decision, including the 21 SETA SSPs, stakeholder recommendations, literature sources and interviews with stakeholder representatives. Based on the qualitative analysis, the final list of occupations in current as well as future demand excluded 14 from the original list of 143 occupations. The OIHD with potential relevance to the Water Sector included: Engineering Manager (132104), Civil Engineer (214201), Civil Engineering Technician (214202), Contract Manager (121904), Financial Manager (121101), Water Plant Operator (313201), Mechanical Engineering Technician (214402), Mechanical Engineer (214401), and Environmental Engineer (214301).

2.2.5 WRC – Water Research Commission

Afrosearch and Hlathi Development Services collaborated on the '*Assessment of Training Programmes and Capacity Needs for the Water* Sector' project for the WRC and presented the final project report in March 2007 (Afrosearch and Hlathi Development Services, 2007). The project originated due to a lack

of skills at local government level required to address the water and sanitation services backlog, with a particular focus on rural municipalities. The objectives of the project were as follows:

1. To review water sector-relevant policies, legislation and reports on the state of municipal capacity and skills requirements.
2. To assemble an inventory of water sector-relevant accredited and non-accredited degree, diploma and short training courses (public and private sector) specifically aimed at building capacity for water services delivery, water resources management and future water research.
3. To assess whether the available training addresses the skills requirements of the water service authorities and water services providers (i.e. a skills gap analysis and recommendations for addressing the capacity gaps).

The following methodology was utilised to determine the skill demand/needs of water services authorities and water services providers.

1. Develop a typical or generic municipal organogram for water services authorities and water services providers based on an analysis of legislation governing municipal functions. Departments within a municipality and units within departments were specified.
2. Conduct a web / online search of municipal vacancies to obtain information on occupations within municipalities, including job titles, duties, minimum qualifications, department within the municipality, etc.
3. Combine the information obtained from the web search with the organogram to populate the organogram with more detail regarding individual occupations. Verify and extend the list of occupational categories using other publications.
4. The function of each occupation was used to identify the foundational, generic and task-specific skills and capabilities (competencies) required. A matrix of skills requirements per occupational category was developed.
5. A preliminary estimation of the number of occupation / positions in demand (to be filled) was made using
    a. the number of additional staff required to meet service delivery targets contained in the 2010 Millennium Development Goals (addressing water supply and sanitation backlogs)
    b. the number of additional staff required to ensure sustained municipal service delivery in the medium and long term.

The following skills gaps were identified in the study:

1. A shortage of engineering professionals at municipalities due to increased competition with the private sector.
2. An emphasis on providing training to lower-level technical staff at municipalities, with funding for learnerships directed towards NQF levels 1 to 5. While this training is necessary, no corresponding learnerships are offered to provide higher-level (postgraduate, NQF 6 to 8) technical training required.
3. A shortage in health and hygiene practitioners, especially at rural municipalities where the greatest need for education in health and hygiene education exists.
4. A general shortage of financial, strategic management, leadership, community development and entrepreneurship skills at most municipalities.
5. A lack of skills (and knowledge) required to convert policy into practice.

Based on their findings, a number of recommendations were made, some of which were:

1. The establishment of an entity to coordinate training and capacity building in the water sector. Amongst other functions, this national coordinating body should consult stakeholders, establish partnerships with tertiary institutions and training service providers to supply training, fund and monitor the progress of skills development, and evaluate whether skills supply initiatives meet the demand for skills.
2. To address the shortage of engineering and technical skills, the establishment of a water and sanitary engineering training programme was recommended.
3. The allocation of more resources to train Community Health Workers and Environmental Health Practitioners for deployment at rural municipalities.
4. The development and implementation of strategic management, leadership, and financial management training programmes.

A number of years later the WRC commissioned the project '*Integrated Water Sector Skills Intervention Map based on a Sector Skills Gap Analysis'* on behalf of the DWS. The final project report was published in March 2015 (Vienings and Lima, 2015).

The aim of the project was to develop a robust methodology to assess the skills status of the sector to (i) enable accurate decision making and planning, and (ii) ensure that the water sector fulfils its responsibilities. The methodology developed during the project was used to assess both institutional capacity as well as individual skills; where '*capacity*' refers to the number of staff required per job title per institution and '*skills*' denote the competencies required by an individual to perform their job.
Only four public water sector institutions were considered in the report, including the DWS, the Breede-Overberg Catchment Management Agency (CMA), Umgeni Water (Water Board) and Moses Kotane Local Municipality (Water Services Authority). Furthermore, only technical positions that require semi-skilled and skilled staff were included in the research.

The report summarised five methods developed during the course of the project:

1. Capacity Gap Method: used to determine the difference between the capacity supply and demand at a particular institution.
2. Skills Gap Method: used to determine the difference between the supply of skills (skills held by staff) and the skills demanded per job.
3. Water Sector Competency Framework: was developed by the research team in collaboration with expert professionals. It contains a comprehensive list of water sector functions with associated competencies and skills requirements and covers more than 2500 technical skills.
4. A Skills Matrix: outlines the skills required per job title.
5. An Online Skills Survey System: developed to gather information on the skills of individuals (www.waterskills.co.za).

The Capacity Gap and Skills Gap methodology developed during this project was endorsed by 91 representatives from various water sector institutions, and recommended for adoption as best practice in the sector.

The authors note that the findings of the project were limited due to the following reasons:

1. Difficulty in obtaining participation from a variety of water sector institutions. The majority of findings were based on only four public institutions.
2. The supply of skills (skills held by staff) was assessed using an online survey system, which proved to be challenging due to slow internet connections at public institutions.

3. The Capacity Gap Analyses performed for the CMA and the Water Services Authority indicated a 44% and 58% gap, respectively. On the other hand, the analysis conducted for the Water Board suggested that more staff was employed than required, leading the authors to question the accuracy of the method when applied to a water board.

The authors also determined whether Higher Education Institutions (HEIs) produced sufficient graduates to fulfil the capacity gaps identified during the project. The analysis revealed that the number of graduates with water sector relevant engineering and science qualifications had increased substantially during the preceding 5 years. The report recommended additional research to determine how many of these graduates found employment at public and private water sector institutions. This recommendation is the aim of a WRC-funded project, which is conducting a 'Trace Study of Water PhDs in South Africa' (Pouris and Thopil, 2020).

A bibliometric analysis of published PhD theses with titles related to water and sanitation has identified 112 PhD graduates between 2013 and 2017. Contact details (telephone numbers or email addresses) were obtained for 100 of the 112 doctoral graduates from social media and publicly available databases. A questionnaire was distributed via email to these graduates to elicit information regarding doctoral education, early career research positions, employment, international mobility, career-related experience and personal demographics. Of the 112 profiles, 107 of the PhD-holders were traceable. Analysis of the results indicated the following:

1. The majority of respondents were located in Africa (87.5%) and more specifically, 62.5% in SA. This indicated that some graduates left SA and returned to their country of origin; this is noted as a potential source of concern to the DHET, Department of Science and Innovation and DIRCO.
2. All graduates were employed at the time of the survey. The majority were employed at academic institutions, followed by private, governmental, and semi-governmental organisations. Nearly a quarter of respondents from academic institutions were employed in short-term positions as post-doctoral fellows.
3. The majority of the graduates remained in occupations related to the water sector (nearly 90%), with only 18 of the respondents having moved to a different sector since graduation.
4. The authors concluded that the results of the survey indicated that the Water Sector can absorb more graduates with doctoral degrees, although cognizance should be taken of the fact that a number of graduates left SA after completion of their studies.

The WRC is currently funding a cross-sectoral PhD tracer study to "*trace the mobility and career paths and other attributes of a representative sample of PhD graduates from South Africa universities across a range of sectors and disciplines*" (WRC, 2020).

The application of the Capacity Gap methodology developed during the '*Integrated Water Sector Skills Intervention Map based on a Sector Skills Gap Analysis'* project was the aim of a subsequent WRC project. The final report, published by Water Concepts in 2018 was entitled '*Application of the Water Sector Capacity Gap Method to Two Proto-CMAs and a National CMA'* (Vienings et al., 2018). The initial aim of this project was to apply the Capacity Gap and Skills Gap Methods to two proto-CMAs (Limpopo CMA and Pongola-Mtamvuna CMA). During the course of the project, the primary aim was adjusted twice; firstly, to omit the application of the Skills Gap Method in favour of applying only the Capacity Gap Method to all 9 CMAs, and secondly to develop an organogram / propose an institutional structure for a national CMA.

Secondary aims of the project included the refinement of several of the previously developed methodologies. The Capacity Gap Method and the Skills Matrix/Bank were refined prior to its application to the CMAs. The online survey tool was also modified to streamline the skills gap analysis process, and video material was developed to assist those using the online survey tool. A brief summary of these methodologies are outlined below to illustrate the process of determining Skills and Capacity Gaps at water sector institutions.

A Gap analysis consists of calculating the difference between demand and supply. In this methodology, 'capacity' refers to a particular institution whereas 'skills' refers to an individual (or an institution when all employees' skills gaps are aggregated).

In the Capacity Gap Method, the supply is equal to the number of staff employed per job title and the values are obtained from payroll information. The demand is equal to the number of staff per job title required by the institution to fulfil its water related functions. This value is derived using the following process:

1. Examine the legislation pertaining to an institution to determine its function or responsibilities.
2. Use technical information to quantify the size or extent of the function, in terms of a measurable unit, e.g. the total value of projects managed (in Rands) or the volume of water treated per day (ML/d).
3. Propose a relationship between the measurable unit and the number of job titles (with appropriate qualification) required, e.g. 1 water treatment plant operator per 2.5ML/d (also referred to as a staffing norm).
4. The extent of the company's responsibility is divided by the amount of work one staff member can perform in a year to yield the number of staff per job title required (demand).

An illustration (taken from Vienings et al., 2018) of the results of a Capacity Gap Analysis is shown in Figure 1.

For the Skills Gap Method, the skills demanded by each job title are derived from the previously developed Water Sector Competency Framework and the Skills Matrix/Bank. The Competency Framework consists of 4 levels, the first of which contains all functions related to the water cycle, ranging from water resources, to water services and sanitation. Each function in turn contains competency clusters, which includes competencies related to planning, design, construction, operation as well as regulation. The final level consists of the skills required for the various competencies. The Skills Matrix/Bank establishes the subset of technical skills required per job title (demand) as well as the level of competency associated with each skill, with a rating of 1 (no demonstrated competency) to 5 (fully competent with all relevant formal training and workplace exposure).

Function	Job Title	Qualification held	Actual Years' Experience	Demand	Supply	Gap
WU Authorisation	Water Use Officer	National Diploma (Microbiology)	5 years	10	8	2
Water Quality	Laboratory Technician: Microbiology	National Diploma (Microbiology)	3 years	7	2	5
Design	Technician: Design	N4 Diploma (Civil Engineering)	5 years	3	3	0
Construction	Project Manager	BSc. Eng. (Civil Engineering)	10 years	2	0	2
TOTAL				**22**	**13**	**9**

Figure 1: An illustration of the results of an institutional capacity gap analysis, according to the methodology developed by Vienings et al. (2018)

The supply of skills and associated level of competency in each skill refer to those held by employed staff members. Skills supply is determined using an 8-step process and requires the participation of the Institutions' Human Resources staff as well as the personnel who will be assessed. The sequential steps to be followed are as follows:

1. Obtain participation from in the institution
2. Liaise with management to appoint and train a skills audit champion and skills audit team from the institution's HR department
3. Confirm and implement a timeline for the completion of the skills audit
4. Communicate with the personnel who will participate in the skills audit regarding the purpose of the assessment, the manner in which it will be conducted and the responsibilities of the staff / line managers
5. Each personnel member completes a self-assessment of their skills set with competency rating using the Online Skills Survey (www.waterskills.co.za)
6. These self-assessments are forwarded to the line manager for ratification; this step is crucial to ensure that the information supplied is as valid and accurate as possible
7. If there are differences between the self-assessment ratings and that of the line manager, HR must establish a panel discussion to determine the final outcome
8. Once completed, the results are compiled in the database to yield the skills supply of the institution.

An illustration (taken from Vienings et al., 2018) of the results of a Skills Gap Analysis is shown in Figure 2.

FUNCTION	COMPETENCY CLUSTER	COMPETENCY	SKILL	JOB TITLE: Laboratory Technician: Microbiology			TRAINING PLAN
				Demand	Supply	Gap	
Water Resources Environmental/ Scientific Services	Laboratory Work	Equipment/ Instrumentation Care	Implement care procedures for sterilisation equipment.	5	5	0	i.e. fully competent
		Sub total		**5**	**5**	**0**	
		Sample Analysis and Interpretation	Adhere to client service level agreements.	5	4	1	**i.e. requires further workplace experience**
			Analyse microbiological samples according to procedures.	5	5	0	i.e. fully competent
			Capture results and operate a laboratory information management system (LIMS).	5	2	3	**i.e. requires further formal training**
			Conduct controls to assess quality of results from samples.	5	4	1	**i.e. requires further workplace experience**
			Follow "good laboratory practice".	5	5	0	i.e. fully competent
			Follow safety procedures.	5	5	0	i.e. fully competent
			Interpret results of microbiological sample testing.	5	4	1	**i.e. requires formal training and further workplace experience**
			Maintain documentation of results according to procedures.	5	5	0	i.e. fully competent
			Use all equipment correctly and according to the quality control system.	5	5	0	i.e. fully competent
		Sub total		**45**	**39**	**6**	
		Sample Collection and Preservation	Collect and preserve microbiological samples.	5	5	0	i.e. fully competent
		Sub total		**5**	**5**	**0**	
TOTAL				**55**	**49**	**6**	

Figure 2: An example of a Skills Gap Analysis taken from WRC report by Vienings et al. (2018)

These methodologies used to determine the skills and capacity gaps at water sector institutions were proposed and accepted as *best practice* in the sector. While these methodologies are certainly comprehensive, the application is time-consuming and expensive.

The first WRC report *Integrated Water Sector Skills Intervention Map based on a Sector Skills Gap Analysis* (Vienings and Lima, 2015) note that SA contains more than 380 public water sector institutions, with an estimated staff complement of 28 000. This does not include private institutions and staff numbers. A complete skills and capacity gap analysis for 1 institution was estimated to cost R200 000, besides the amount of time required to complete such an assessment. In light of this, the scope of any water sector skills demand audit should therefore be considered carefully and defined prior to commencement.

2.2.6 iWETs – Improving Water Education and Training Skills in South Africa

Improving Water Education and Training Skills in SA (iWETS) is an initiative sponsored by the Dutch government in response to a request from the Development Bank of Southern Africa's Vulindlela Academy. The mandate of this academy is to facilitate capacity building at local authorities, including those involved in the water sector. The collaborative project *'Vision for Water Capacity Building in South Africa'* is the result of this request and Phase I of the project outlined the water sector, water education and water training and skills development, and maps out an implementation plan to improve capacity building for water practitioners in SA and Africa. The implementation plan outlines priorities and proposes several projects to address the sector needs (Maenhout et al., 2012).

The Phase I report drew on existing research / analyses of the current state of the water sector and made its own recommendations (Maenhout et al., 2012). The report notes the following:

1. Only a few Universities and TVET Colleges offer formal, accredited qualifications related to the water sector. The number of students enrolled in these programmes are small.
2. There are no specialised water and sanitation qualifications for NQF levels 2 to 6, resulting in the need and opportunity to develop formal water-related qualifications for the TVET College sector.
3. Existing curricula are not designed to meet the demands/needs of the sector and do not allow for defined career paths/progression.
4. Teachers do not possess the necessary knowledge to effectively train students.
5. The water sector is not an attractive option for students.
6. The list of occupations required for a functional water sector depends on the source of the report and varies greatly. A large number of water-related occupations are not listed in the OFO and therefore do not have an OFO code. The lack of a consolidated list of required occupations with associated career description, path, and profile greatly complicates planning, skills development and skills demand tracking efforts.
7. The sector is diverse, consisting of more than 358 organisations and requires skills at all levels, yet, there is a lack of appropriate methods to quantify the need for education, training and skills development in the sector.
8. The planning for skills requirements and education provision is not coordinated.
9. The number of EWSETA-accredited training service providers has decreased and the sector needs are not being met by the available courses. This situation has likely contributed to the increase in ad hoc training offerings (including short courses) that do not comply with accredited unit standards.
10. The education of water professionals cannot stop after graduation. The field requires professionals to continuously incorporate technological advances and therefore should

encourage the development, implementation and maintenance of lifelong learning. This implies that training service providers, including education institutions should be involved in this process.

The report highlights the following areas requiring intervention (Maenhout et al., 2012):

1. Improving the ability of the water sector and the SETAs to undertake a sector skills needs assessment, to develop an education/training plan to address the needs, and to execute the plan.
2. Improving the relationship between the water sector, HEI, TVET Colleges and regulatory bodies to effectively coordinate education/training for engineering and scientific professions.
3. Coordinate and ensure the quality of on-the-job training initiatives and lifelong learning programmes.

2.2.7 NSTF – National Science and Technology Forum

The National Science and Technology Forum (NSTF) is a non-profit organisation, representing more than 100 stakeholders with an interest in science, engineering, technology and innovation. These stakeholders include science councils and statutory bodies, businesses, state-owned enterprises, civil society, government, higher education as well as professional bodies. One of the objectives of the NSTF is to influence science, engineering, technology and innovation policies; to achieve this goal, it hosts NSTF Discussion Forums to promote government and stakeholder interaction. One such a Discussion Forum, focussed on 'Skills drought in the Water Sector' took place over the course of 2 days in September 2016.

The objectives of the forum were to:

1. 'Facilitate the exchanges and solution-driven deliberations' relating to the SA water crisis
2. Plan for the skills that would be required within the next 10 to 20 years
3. Provide a platform for the RDI community to deliberate the lack of scarce water sector skills
4. Influence and respond to policymakers (government, business community, as well as agricultural, industrial, and mining sectors).

The content of the presentations and discussions were captured and the proceedings made available online. Selected highlights pertaining to skills demand in the water sector gleaned from the proceedings were as follows:

- The DWS had in the past relied primarily on engineering and technological skills, but the policy shift to assign water management to catchment areas created the need for skills related to economics, regulations, law, accountancy and community engagement (i.e. water use authorisation and licencing, water use charges, pricing strategy, property expropriation, conflict management and trade-off negotiation).
- A local government skills audit, commissioned by Cabinet in 2008, identified a below average competency level. Remedial actions included the institution of regulations governing the appointment of senior managers in 2014, the implementation of a guideline standard organogram for municipal water services authorities and water services providers, and the training of process controllers on the requirements for Green and Blue Drop certification.
- The establishment of the DWS Learning Academy to ensure the provision of engineers, scientists, technologists and technicians to the department was highlighted.

- Future skills requirements and the need for education institutions to adapt to these were discussed, including the effect of climate change and its impact on the water-food-energy nexus, the limited availability of water, equitable distribution of water to all communities in SA, and promoting a change in consumer behaviour with respect to water. HEI would need to decide whether the conventional training / discipline offerings would be sufficient to supply such future skills requirements.
- A shift in the research focus areas since 2010 from topics such as 'treatment, chemistry, irrigation, sludge, industry and effluent' to topics involving 'sustainability, social, community, demand, integration, management, planning, urban development, complexity and adaptation' indicates that research institutions are adapting to incorporate new disciplines and develop new skills in water-related RDI. Technological advances have facilitated the era of 'big data' and students at HEIs were utilising this to build water-use monitoring devices and develop new models to understand the interaction between water quality and water use, for example.
- The establishment of centres such as the University of Cape Town's Franschhoek Water Hub could facilitate the practical training and skills development of students, alongside the development and demonstration of innovative technologies.
- Water resource management will require developing skills in adaptive management, especially as it relates to decision-making in complex and interactive social-ecological systems in the face of an uncertain future.
- Innovative technologies are being developed to reduce water use, especially related to sanitation, e.g. recycling up to 80% of water in households as well as developing low-flush toilets and dry sanitation systems. Other areas being targeted include water re-use, reducing non-revenue water by limiting physical losses due to leaks in the reticulation system, as well as energy generation and resource recovery from wastewater.
- Graduates from HEIs were not being employed and strategies to retain employees were not in place. Increased investment in research and knowledge-creation facilities were required and training should be more practical. A deficiency in practical workplace experience opportunities for engineering students was a major challenge.
- The provision of career guidance to high-school learners was identified as an important intervention to promote water sector qualifications and careers.
- Suggestions were made to re-instate the past practice of offering mentorship and creating opportunities for graduates to attain practical experience in the workplace. The Young Water Professionals Programme was noted as providing career advice and mentoring by industry-affiliated professionals.
- Discussions between educational institutions and industry were essential to determine which qualifications were specific to the water sector. Provision of training for these qualifications requires qualified lecturers. The identification of new skills was required.
- The registration of young professionals with professional bodies [e.g. the Water Institute of South Africa (WISA) or Engineering Council of South Africa (ECSA)] should be promoted.
- The poor quality of training provided by TVET colleges forced industry to employ graduates from these programmes as labourers or to re-train them.
- The production of skills requires time. Transdisciplinary skills are required to solve problems in the sector and the ability to work in collaborative teams is essential.
- The DHET and DSI should be made aware that more postgraduate students and scientists are needed in the sector. Postgraduate students should be integrated into multidisciplinary teams to foster skills development and gain practical experience. These teams should focus on innovation.
- The DST and DWS should support training of industrial engineers. The water sector and prospective students should be made aware of the contribution that this profession can make to the sector.

2.2.8 ACEWater 2 – African Centres of Excellence Human Capacity Development Programme

The African Union (AU) and New Partnership for Africa's Development (NEPAD) Water Centres of Excellence was created in 2006. The network consists of three Centres of Excellence in Western, Southern, and Central/East Africa. The aim of the African Centres of Excellence Human Capacity Development Programme (ACEWater 2) is to increase capacity for sustainable development in the water sectors of the affiliated countries. A recent draft report on the Priorities of Human Capacity Development in the African Water Sector (2019) noted the results of surveys into priority training requirements at higher education/young professionals and technical vocational education levels conducted for each of the participating countries.

The Southern African Network of Water Centres of Excellence (SANWATCE), consisting of Botswana, Malawi, Mozambique, Zambia and South Africa identified various as priority areas for training. A summary of the preliminary results and methodologies used to gather the information follows in Table 4.

2.2.9 South African Economic Reconstruction and Recovery Plan

The aim of the Economic Reconstruction and Recovery Plan (ERRP), published by the South African government in 2020 midst the COVID-19 pandemic, is to stimulate equitable and inclusive growth. One of the nine priority interventions the ERRP identified is "green economy interventions". Green industrialisation can be linked to the water sector as it guarantees the security of water supply, amongst others. The ERRP states that as part of South Africa's green agenda, private and public buildings will be retrofitted with measures to improve water efficiency. The creation of 1560 new opportunities is earmarked in the plan for "facilities maintenance, water and energy efficiency, and construction of rural bridges".

Furthermore, one of the eight key enablers of the plan is "skills development" while one of the nine structural reforms which will support economic reconstruction and recovery is "boosting skills education and skills development". Skills development in the ERRP is focused on, amongst others, a comprehensive skills audit to determine the skills requirements and available skills in South Africa; to up-scale the production of artisans to drive the delivery and maintenance of infrastructure and to invest in programmes which will bring the youth into workplace based learning. A requirement for all infrastructure projects will be to contribute to the development of newly skilled artisans, thus providing skills on a sustainable basis (ERRP, 2020).

Table 4: A summary of the priority training areas identified in each of the 5 countries participating in SANWATCE and the methodology followed to determine these.*

Country	Priority Training	Survey sources
Botswana	Young professionals: 1.Isotype Hydrology 2.Integrated Groundwater-Surface water Hydrology Technical Vocational Education level: 1. Borehole drilling and well maintenance 2.Groundwater monitoring and analysis	13 reports Interviews with stakeholders Questionnaires to stakeholders National Dialogue Workshop Validation Workshop
Malawi	Key competencies required include water resource investigations, monitoring and pollution control, project management, GIS and remote sensing, surveying and communication. High education level: 1.MSc in Water Resources Modelling and Governance Programme (Principals of Hydrology, Hydrological Modelling and Water Quality Management) 2.MSc in Infrastructure Development and Management (Water Supply and Sanitation) Technical Vocational Education level: 1.Certificate programme for Water Technicians 2.Apprentice Diploma programme for Water Technicians	23 reports Interviews using a guided questionnaire Online questionnaire National Dialogue National Validation workshop
Mozambique	Priority areas for training include Design, update and management of Mozambique's water sector database, Community participation and education, Purification and recycling of water, loss reduction in water infrastructure, water quality assessment and governance and economics of water. Higher Education Level: 1.Water Quality Management 2.Water Economics and Governance 3.Integrated Water Resources Management Technical Vocational Education level: 1.Monitoring and Evaluation of Water Quality 2.Design and Assembly of Different Water Supply Systems	29 reports Stakeholder interviews using semi-structured questionnaires National Dialogue workshop Two validation workshops
Zambia	Operational hydrology, dam safety, hydrological modelling, unmanned aerial surveying and information management, regulation of water supply and sanitation tools, tariff setting processes and economic regulation. Higher Education Level	16 documents Meetings and discussions

Country	Priority Training	Survey sources
	1.Water Resources Monitoring 2.Integrated Water Resources Management 3.Environmental Quality Modelling 4.Groundwater Modelling Technical Vocational Education level 1.Drilling Methods and well completion 2.Field Hydrogeology 3.Pumping Test and Analyst Tools	National Dialogue Workshop Two validation workshops
South Africa	Shortage of specific critical skills within the water value chain, e.g. engineering, socio-economic and environmental health.	27 reports National scoping study Interviews Questionnaire survey National Dialogue Workshop National Validation Workshop

* It should be noted that these are preliminary results from a draft report (ACEWater 2: Priorities of Human Capacity Development in the African Water Sector, 2019).

2.3 FUTURE SKILLS DEMAND IN THE WATER SECTOR

In 2017, KPMG was recruited by the Water Services Association of Australia (WSAA) and the Water Environment & Reuse Foundation (WE&RF) to investigate the future skills required by the workforce in the water sector and the key future trends impacting on the water sector. The report outlines 8 key factors that drive change and that may aid the water sector to prepare for future opportunities, challenges and risks (WSAA & WE&RF, 2017). The 8 key factors identified to drive global change consisted of: 1) resilience (flexibility, agility, critical thinking), 2) data and analytics (digital literacy and the internet of things), 3) leadership (strategic planning, management, learning, communication, culture), 4) the customer (service, culture, experience), 5) technical skills (network operations, engineering, general operation, risk management, knowledge management), 6) delivery models (contracting, outsourcing, insourcing), 7) entrepreneurship (innovation) and 8) collaborations (partnerships with other sectors).

Specifically, the water sector is impacted by factors such as rising customer expectations regarding service delivery, rapid digitalization of services, communities expecting to be involved in decision making, community antagonism to service interruptions, an aging workforce, automation of routine processes, cost reduction via operational improvement and efficiency, asset management in drier climates (including the impact of climate change), increased competition in the water services market and changes in regulations, benchmarks outlined in the United Nations Sustainable Development Goals and the heightened awareness to better manage vulnerable customers (WSAA & WE&RF, 2017).

In addition to these global key trends, the water sector is also influenced by key industry trends that include: integrating customer insights into traditional networks, digital utility, smart networks (IT architecture), more sophisticated customer engagement, incentives and improved asset management. It is therefore of utmost importance that the future workforce is resilient and flexible, they are data savvy, they develop leadership skills, they are customer orientated, they have the required technical skills and they are innovative to meet future water demands (WSAA & WE&RF, 2017).

The report ultimately recommends that the water sector should build a brand that excites and motivates current and potential employees to consider working in this industry; the water sector should invest in career development to upskill employees and to provide employees with a clear career trajectory; the water sector should become passionate about their customers and determined to meet the demands of the customer; the water sector should commit to diversifying their workforce as a mix of employees bring different opinions and insights to the table and the water sector should focus on the employee experience where the opinion of the employee is of great importance, the employees have a sense of purpose and the employee is appointed in positions proportionate to their expertise which will aid in developing a reliable workforce able to meet dedicated targets (authority is given to experts) (WSAA & WE&RF, 2017).

More recently, the South African Academy of Engineering (SAAE) addressed a letter to President Cyril Ramaphosa on how the water sector in South Africa would need to improve, especially considering the ongoing Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) outbreak. The advisory note highlighted that infrastructure needs to improve to ensure reliable and adequately treated water is distributed to urban centres as well as rural areas (SAAE, 2020). This requires prioritizing strategic investments which may be achieved by implementing an infrastructure development program. This may then create jobs, promote economic activity and contribute to water security. In addition, wasteful investment and incompetent management of resources need to be halted in order to ensure

sustainability in the water sector (SAAE, 2020). Furthermore, the nation's water management institutions need to be rebuilt by developing and empowering resource planners and managers who will be able to effectively monitor, guide and manage the use of water (SAAE, 2020). Lastly, citizens need to be involved in the sector by being informed of the state of our natural resources and implementation of local action to address local problems (SAAE, 2020). These areas of improvement then link to the need for adequately qualified water professionals in engineering, science and social science, focusing on various aspects of water management and infrastructure. Furthermore, it highlights the need to involve citizens in water processes and the implementation of improved water management programs (SAAE, 2020).

The GreenCape Water: Market Intelligence Report (2019) then highlighted the main market opportunities for the water sector. These include opportunities in: metering and monitoring; water efficient technologies; reuse and alternative water treatment systems; brine management solutions; and water efficient devices and technologies. These opportunities in turn underscore the need for skills in developing: reuse and alternative water treatment systems; water efficient technologies and metering and monitoring systems. This can then be related back to the future skills highlighted in the KPMG report where: technical skills; digitalization, the internet and smart networks; consumer-based economics; data and analytics and collaborations between sectors are of vital importance. It is thus clear that the water sector is South Africa will require skills related to science, engineering, Information Technology, business, management, social science, creativity, entrepreneurship, innovation, etc.

CHAPTER 3: METHODOLOGY

3.1 DATABASE COLLECTION

A comprehensive database was established for the skills demand study which included water sector-related entities in the public and private spheres. Entities included, amongst others, Cape Nature, CMAs, DEA&DP, DWS (national and regional offices), district municipalities, ESKOM, EWSETA, LGSETA, local municipalities (metros, medium and small), public research organisations such as Agricultural Research Council (ARC) and Council for Scientific and Industrial Research (CSIR), South Africa Local Government Association (SALGA), Trans Caledon Tunnel Authority (TCTA), and water boards and utilities.

Entities included in the private sphere of the water sector, amongst others, were commercial farming establishments, Endangered Wildlife Trust, irrigation boards, large and medium-sized consulting firms, mining houses, private research organisations, and wine estates.

3.2 QUESTIONNAIRE

A concise and carefully constructed online questionnaire was compiled and circulated to all entries listed in the database of water sector skills stakeholders through the Stellenbosch University SUNsurvey online platform. Approval for the questionnaires of this project was obtained from the Social, Behavioural and Educational Research ethics committee of Stellenbosch University (REC-2019-9608).

The target audience for the online survey included Human Resources managers, skills development personnel, line managers, engineers and water-related researchers. The WRC, through coordination with the Department Science and Innovation (DSI) and DWS assisted by providing a supporting letter for the survey. To obtain participants' consent to be included in the respective questionnaire distribution database, an opt-out clause was inserted into the email communication. The questionnaire was distributed on 21 October 2020 to a sample size of 445 individuals. The Institute of Municipal Engineering of Southern Africa (IMESA) were also contacted for distribution of the survey link, in their newsletter and membership network, respectively. The DWS distributed the survey link to the water boards and members of the Water Sector Leadership Group (WSLG). The online link to the questionnaire remained active for 36 days and closed on 25 November 2020. To increase the response rate, a reminder email with the online link to the survey was distributed on 2 November 2020 and followed by telephone calls to selected key stakeholders.

3.2.1 Occupations and Skills

The South African Organising Framework for Occupations (OFO) was used to list all water-related occupations in the public and private spheres of the water sector (with the RDI environment being the only exception). Each occupation has a six-digit number which relates to a cluster of jobs. The eight Major Groups in the framework, indicated by the first digit in every six-digit number, are Managers (1), Professionals (2), Technicians and Associate Professionals (3), Clerical Support Workers (4), Service and Sales Workers (5), Skilled Agricultural, Forestry, Fishery, Craft and Related Trades Workers (6), Plant and Machine Operators and Assemblers (7) and Elementary Occupations (8). The Major Groups

are further subdivided into Sub-Major Groups, Minor Groups and Unit Groups. Occupations are not identified as part of the structure but listed as sub-divisions of the Unit Groups.

In total, 35 occupations were included in the questionnaire. An occupation is defined by the OFO as *"a set of jobs whose main tasks and duties are characterised by a high degree of similarity (skill specialisation)*". A job is characterised by *"a set of tasks and duties carried out or meant to be carried out, by one person for a particular employer, including self-employment"* (OFO, 2013). Some of the occupations included in the study have more than one specialisation (i.e. job) relevant to the water sector and were therefore further divided in the list of options. Environmental Managers (134901) have; for example, three specialisations listed namely Sanitation Programme Manager, Water Resource Management Practitioner and Water Resource Manager. In total, there was a list with 45 options for respondents to select from. Occupations included in the questionnaire were based on the literature by Vienings et al. (2015, 2018), the sector skills plans (SSP) of EWSETA (2018) and LGSETA (2018a), Labour Market Intelligence Report (2018), Department of Higher Education and Training's list of OIHD (DHET, 2018) as well as the OFO (Version 2019). The criteria used to select the occupations for the skills demand study are discussed in the following paragraph. Refer to Appendix 1 for the list of water-related occupations included in this study.

The questionnaire investigated the skills demand for water-related occupations at a technical to a specialised level. In this study, occupations at technical to specialised level were defined as skills requirements for employees with qualifications with National Qualifications Framework (NQF) levels 6 to 10. Qualifications within NQF Levels 6 to 10 include Diploma Advanced Certificates, Occupational Certificates (Level 6), Advanced and Postgraduate Diplomas as well as degrees obtained at universities. When referring to the Major Groups of the OFO, Managers (NQF Levels 6-10), Professionals (NQF Levels 7-10) and Technicians and Associate Professionals (NQF Level 6) were included. The scope of the questionnaire was further defined by occupations requiring technical skills referring specifically to engineering and scientific skills (Vienings et al., 2018). Based on this definition, Finance Managers (121101) and Contract Managers (121904), for example, were not included in this study.

Every occupational grouping (up to 4th digit level) has a list of associated tasks, the output of the respective occupation. This common set of tasks was used as basis for generating the skills sets for the current study. All the tasks in the OFO (2019) relating to the 35 occupations were compiled and duplicates removed to provide a list of 200 tasks. From the list 74 generic skills were identified which are required to complete these tasks. These skills were grouped under the headings: Technical Skills, Management, Planning, Operational, Research, Development and Innovation/Scientific Services, Technology and Innovation, Financial, Human Resources, and Contract Management. Respondents were required to complete the skills table for each respective occupation selected. The information collected was used to construct the skills matrices.

Occupations relevant to institutions and organisations involved in water-related RDI activities included in this study were Laboratory Technician, Project/Research Manager, Research and Development (R&D) Manager, Researcher, and Technology Transfer Officer. The OFO was not used in the RDI environment since Technology Transfer Officer is not present in the framework. Furthermore, the OFO only has occupational codes for a Microbiology Researcher (2019-213108) and Ecological Researcher (2019-213301) but not for researchers involved, for example, in social sciences or research in the engineering fields. The same applies for a Laboratory Technician, with occupational codes present for a Chemical Laboratory Technician (2019-311101), Physical Sciences Laboratory Technician (2019-311102), Geotechnical Laboratory Technician (2019-311201), Civil Engineering Laboratory Technician (2019-311201), Electrical Engineering Laboratory Technician (2019-311301), Geoscience Laboratory

Technician (2019-311704), Earth Science Laboratory Technician (2019-311704) and Agricultural Laboratory Technician (2019-314201), but not for laboratory technicians involved, for example, in water-related microbiological research.

To compile the skills sets for the RDI environment literature for a Project/Research Manager (Sunindijo, 2015), Researcher (Purcell et al., 2005; Pouris and Thopil, 2020), Laboratory Technician (Lewis, 2017) and Technology Transfer Officer (Mom et al., 2012) were studied. The skills in the literature were combined, duplicates removed and grouped under the headings Technical Skills, Management, Planning, Operational, Research, Development and Innovation/Scientific Services, Technology and Innovation, Financial, Human Resources, and Contract Management. Respondents were required to complete the skills table for each respective occupation selected. The information collected was used to construct the skills matrices.

3.2.2 Vacancies

Respondents completing the questionnaire were requested to indicate the occupations which are currently vacant in their organisation of employment. This section not only provided information on the available jobs in the sector, but high vacancy rates have also been identified as an indicator of scarcity by SETA's scarce and critical skills research (OFO, 2013). Respondents were also requested to indicate the reasons for each vacant occupation. The list of reasons for vacant positions was taken from the EWSETA Sector Skills Plan and further adapted for the current study (EWSETA, 2019). The options respondents could select from were as follows: candidates are not registered with professional bodies; lack of relevant experience; lack of relevant qualifications; new or emerging job; poor remuneration; slow recruitment process; unsuitable job location; unsuitable working hours and economic climate.

3.2.3 High Staff Turnover Rate

Respondents completing the questionnaire were requested to indicate the occupations which have a high staff turnover rate in their organisation of employment. High staff turnover rates, together with high vacancy rates, are seen as an indicator of scarcity by research conducted by the SETAs scarce and critical skills research (OFO, 2013). Respondents were also requested to indicate the reasons why certain occupations have high staff turnover rates. The options respondents could select from were taken from the Local Government Skills Forecasting Model prepared by the CSIR (LGSETA, 2016) and further adapted for the current study. The options respondents could select from were as follows: Contract closure; Dismissals; Resignations; Retirement and Economic climate.

3.2.4 Upskilling and/or Reskilling of Current Employees

Respondents completing the questionnaire were requested to indicate the occupations which require the reskilling and/or upskilling of current employees in their organisation of employment. Respondents were requested to indicate how the current employees are reskilled and/or upskilled. The options respondents could select from for learning interventions were taken from the EWSETA SPP (2019) and further adapted for the current study. The options included: formal qualification at institute of higher education; professional registration and Continuous Professional Development (CPD); short courses and workplace learning (mentoring system).

3.3 FOCUS GROUP INTERVIEWS

Focus group interviews were held to collect and validate data on the following themes: occupations and skills; graduate and postgraduate skills demand and addressing skills gaps in the water sector. Stakeholders were identified and focus group interviews were held for each for the following sectors: agriculture; CMAs; consulting/engineering; water-related RDI; manufacturing; mining; municipalities; national or provincial government and water board or utility. Semi-structured interviews were held or written input was obtained where identified stakeholders were not available for a sectoral focus group interview. An online platform was used for all the interviews.

3.3.1 Occupations and skills

To validate and triangulate the information generated through the online questionnaires, identified stakeholders were requested to indicate if there is a lack of skills amongst water-related occupations (job titles) in their organisation of employment or in the sector in which the organisation operates. Interviewees were further requested to indicate the occupations which are currently vacant or have a high staff turnover rate, respectively, in their organisation of employment.

3.3.2 Graduate and postgraduate skills demand in the water sector

The WRC Water RDI Roadmap (WRC, 2015) has a range of targets around post-graduate student support over a 10-year period. To assess the ability of the water sector to absorb graduates and specifically post-graduates with water relevant skills the identified stakeholders were requested to indicate whether their organisation employ candidates with water-related qualifications at degree (specialised programmes), honours, masters and PhD levels, respectively.

Interviewees were further requested to indicate whether there are any skills or knowledge gaps amongst graduate and postgraduate employees. Interviewees were also requested to make any recommendations or suggestions on how graduate and postgraduate students can be better prepared for a career in the water sector.

3.3.3 Addressing skills gaps in the water sector

To obtain information of how to address skills gaps in the water sector the identified stakeholders were requested to provide information of how their organisation address the lack of the specific skills (skills gaps) amongst personnel and to identify any barriers during the application of learning interventions. Interviewees were further requested to make suggestions of how the lack of the specific skills (skills gaps) can be addressed on a provincial and/or national level and the role key institutions can play.

3.4 FUTURE SKILLS

Semi-structured interviews with key identified stakeholders were held to determine how the demand of skills could change in the future. Stakeholders were requested to indicate factors which they foresee will drive change in the water sector and how it could impact the future demand and supply of skills. A list of factors which could drive change in the future were constructed from literature and provided to the interviewees. The list of factors include: resilience (flexibility and critical thinking); data and analytics (digital literacy, internet); leadership (strategic planning, management, learning, communication,

culture, etc.); the customer (service, culture and experience); technical skills (network operations, engineering, general operation, risk management, knowledge management); delivery models (contracting, outsourcing, insourcing); entrepreneurship (innovation) and collaborations (partnerships with other sectors) (WSAA & WE&RF, 2017). Interviewees were also requested to provide factors, not provided in the list, which they foresee could drive change in the water sector which in turn could impact future demand and supply of skills.

Interviewees were further requested to make suggestions of how key organisations and institutions can prepare for future changes through skills demand. Lastly interviewees were requested how they foresee the COVID-19 pandemic will impact the water sector (e.g. infrastructure needs, working conditions of employees and skills deployment within organisations).

CHAPTER 4: RESULTS AND DISCUSSION

4.1 PARTICIPATION

The questionnaire was distributed to a sample size of 445 human resources managers, skills development personnel, line managers, engineers and water-related researchers. A total of 42 complete responses were recorded with a response rate of 9.44%. When taking the response rate of the organisations (in other words the number of organisations represented by the respondents compared to the total number of organisations present in the database) into account the percentage recorded was 19.79%. While the response rate for the questionnaire was low, there was a broad representation from key organisations with many respondents part of their organisations' senior management. The job titles of the respondents included Chief Operations Officer (1 respondent), Deputy Director (1 respondent), Director (7 respondents), Engineer (2 respondents), Executive (1 respondent), Head of Department (2 respondents), Manager (8 respondents), Researcher (5 respondents), Research Coordinator (1 respondent), Research/Project Manager (2 respondents) and Other (9 respondents). Job titles specified in the Other option included Agricultural Engineer, Associate Professor, Chief Engineer, Freshwater Ecologist, General Manager of Human Resources, Lecturer, Senior Researcher, Senior Scientist, SSP Practitioner, Consultant and Researcher/Volunteer. The largest sector represented by the respondents consisted of the water-related RDI environment at 43%, followed by Consulting/Engineering/Professional Body and national or provincial and government both at 14%. No stakeholders from the manufacturing sector completed the questionnaire (Figure 3).

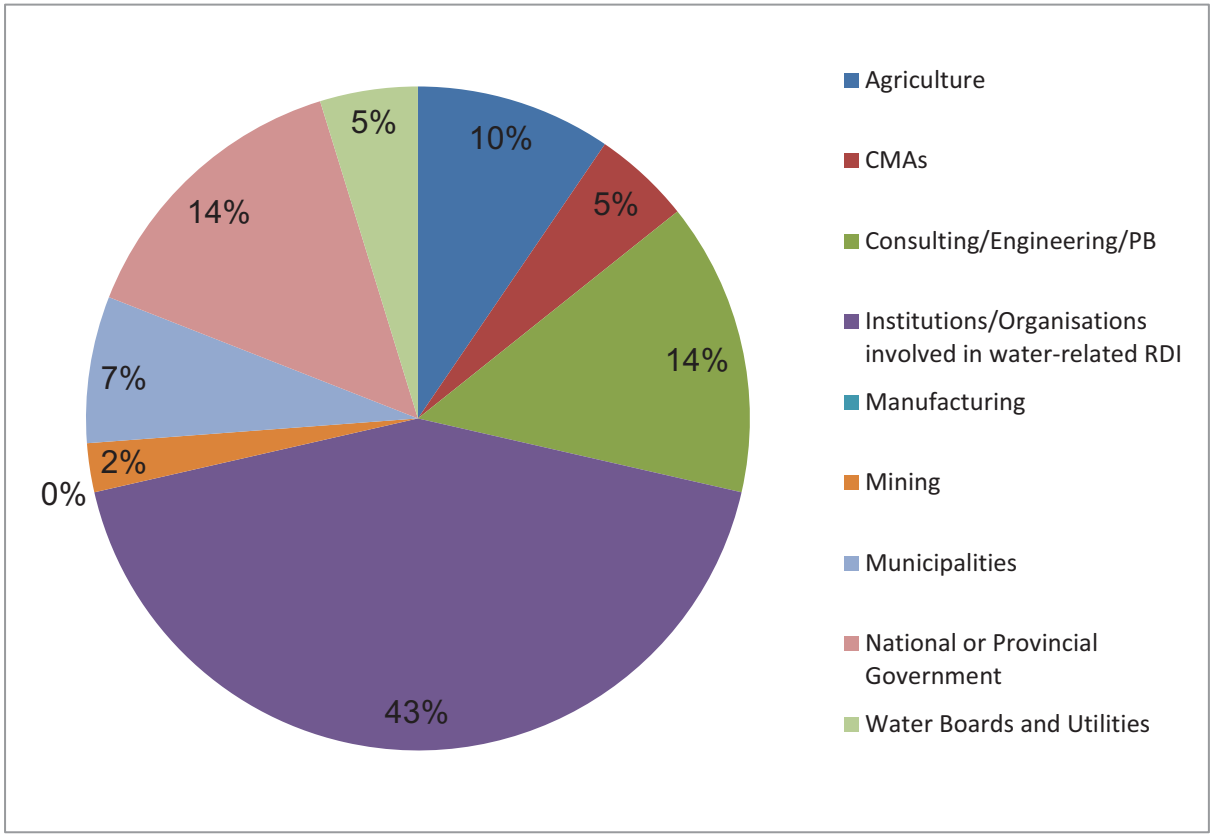

Figure 3: The percentage of respondents which have completed the questionnaire per sector

Four respondents selected Agriculture (ARC, Free State Agriculture, Stellenbosch University and Winetech) as the sector in which their organisations operates in, two respondents selected CMAs (Inkomati-Usuthu Catchment Agency and Natures Valley Trust), six respondents selected Consulting/Engineers/Professional Body [Delta H, Envirosource, SDW Engineers, Self-employed consultant, WISA, WSM Leshika Consulting (Pty) Ltd], one respondent selected Mining (Mintek), three respondents selected Municipalities (De Zalze Winelands Golf Estate, Drakenstein Municipality, Mossel Bay Municipality), six respondents selected national or provincial Government (Cape Nature, DWS, EWSETA, National Institution for Occupational Health) and two respondents selected Water boards and utilities (Magalies Water Board and Wynland Water).

Respondents from 18 research departments of 17 organisations and institutions involved in water-related RDI activities completed the study. The 17 organisations included the departments of eight universities (Rhodes University, Stellenbosch University, University of Cape Town, University of Fort Hare, University of Free State, University of KwaZulu-Natal, University of Pretoria and University of the Western Cape), two universities of technology (Cape Peninsula University of Technology and Durban University of Technology), two research councils and institutions (ARC and Institute of Natural Resources), one water board (Magalies Water) and three private companies [Bosch Capital, Clearedge Projects and Palmer Development Group (Pty) Ltd].

4.2 QUESTIONNAIRE

4.2.1 Occupations and Skills

The South African OFO was used to list the water-related occupations in the water sector (with the RDI environment being the only exception) for the questionnaire. In this chapter the OFO codes for the respective occupations were not included for ease of use. Refer to Appendix 1 for the OFO code for each occupation.

Table 5 lists the number of departments in organisations in the water sector selecting the filled and vacant options for the respective occupations (n = 24). Respondents were also provided with the opportunity to select N/A (not applicable). The highest number of respondents indicated that the occupations GIS Technician (8 respondents) and Microbiologist (6 respondents) are currently filled in their organisations of employments. This was followed by Civil Engineering Technologist (Water and Wastewater Technologist), Communication Coordinator (Water Liaison Practitioner), Environmental Manager (Water Resource Manager), Environmental Science Technician (Water Pollution Control Officer), Environmental Scientist (Environmental Officer), Environmental Scientist (Environmental Research Scientist), Programme or Project Manager and Water Quality Analyst (Wastewater Treatment Officer/Technician) which was selected by 5 respondents each (n = 24) (Table 5). The highest number of respondents indicated that (Data Processing Manager or Data Operations Manager) (3 respondents) is currently vacant in their organisation of employment (n = 24) (Table 5). Two occupations were added by respondents that were not included in the list, namely Freshwater Ecologist and Biochemist.

Table 5: The number of departments/units in organisations in the water sector indicating filled and vacant positions for the respective occupations (n = 24)*

Occupation	Filled	Vacant	N/A
Agricultural Engineer (Irrigation Engineer)	2 (8.00%)	1 (4.00%)	22 (88.00%)
Agricultural Engineering Technologist (Irrigation Engineering Technologist)	2 (8.00%)	1 (4.00%)	22 (88.00%)
Agricultural Technician (Irrigation Technician)	3 (12.00%)	1 (4.00%)	21 (84.00%)
Chemical Engineer	3 (12.00%)	1 (4.00%)	21 (84.00%)
Chemical Engineering Technician	3 (12.00%)	1 (4.00%)	21 (84.00%)
Chemical Engineering Technologist (Environmental (Water, Air, Soil) Technologist)	2 (8.00%)	1 (4.00%)	22 (88.00%)
Chemist	4 (16.00%)	2 (8.00%)	19 (76.00%)
Civil Engineer (Construction Engineer)	1 (4.00%)	1 (4.00%)	23 (92.00%)
Civil Engineer (Hydraulics Engineer)	2 (8.00%)	1 (4.00%)	22 (88.00%)
Civil Engineer (Water and Wastewater Engineer)	3 (12.00%)	2 (8.00%)	20 (80.00%)
Civil Engineering Technician	4 (16.00%)	1 (4.00%)	20 (80.00%)
Civil Engineering Technologist (Construction Technologist)	2 (8.00%)	1 (4.00%)	22 (88.00%)
Civil Engineering Technologist (Hydraulics Technologist)	1 (4.00%)	1 (4.00%)	23 (92.00%)
Civil Engineering Technologist (Water and Wastewater Technologist)	5 (20.00%)	2 (8.00%)	18 (72.00%)
Communication Coordinator (Water Liaison Practitioner)	5 (20.00%)	1 (4.00%)	19 (76.00%)
Data Management Manager (Data Processing Manager or Data Operations Manager)	4 (16.00%)	3 (12.00%)	18 (72.00%)
Electrical Engineer	2 (8.00%)	1 (4.00%)	22 (88.00%)
Electrical Engineering Technologist	1 (4.00%)	1 (4.00%)	23 (92.00%)
Electronic Engineering Technician (Instrumentation Technician or Telemetry Technician)	1 (4.00%)	1 (4.00%)	23 (92.00%)
Engineering Manager (Engineering Maintenance Manager)	1 (4.00%)	1 (4.00%)	23 (92.00%)
Environmental Engineer (Water Resource Specialist)	3 (12.00%)	1 (4.00%)	21 (84.00%)
Environmental Manager (Sanitation Programme Manager)	3 (12.00%)	1 (4.00%)	21 (84.00%)
Environmental Manager (Water Resource Management Practitioner)	4 (16.00%)	2 (8.00%)	19 (76.00%)
Environmental Manager (Water Resource Manager)	5 (20.00%)	1 (4.00%)	19 (76.00%)
Environmental Science Technician (Environmental Technical Officer)	4 (16.00%)	2 (8.00%)	19 (76.00%)
Environmental Science Technician (Water Pollution Control Officer)	5 (20.00%)	2 (8.00%)	18 (72.00%)
Environmental Scientist (Environmental Officer)	5 (20.00%)	2 (8.00%)	18 (72.00%)
Environmental Scientist (Environmental Research Scientist)	5 (20.00%)	1 (4.00%)	19 (76.00%)
Environmental Scientist (Water Use Specialist)	3 (12.00%)	2 (8.00%)	20 (80.00%)
Geologist (Hydrogeologist)	4 (16.00%)	1 (4.00%)	20 (80.00%)
GIS Technician (GIS Operator/Specialist)	8 (32.00%)	2 (8.00%)	15 (60.00%)
Hydrologist	3 (12.00%)	2 (8.00%)	20 (80.00%)
Local Authority Manager (Water Services Provider Manager)	2 (8.33%)	-	22 (91.67%)
Mechanical Engineer (Mechatronics Engineer)	2 (8.00%)	1 (4.00%)	22 (88.00%)
Mechanical Engineering Technician	1 (4.00%)	1 (4.00%)	23 (92.00%)
Mechanical Engineering Technologist (Maintenance Technologist)	3 (12.00%)	1 (4.00%)	21 (84.00%)
Microbiologist	6 (24.00%)	1 (4.00%)	18 (72.00%)
Programme or Project Manager	5 (20.00%)	2 (8.00%)	18 (72.00%)
Surveyor	3 (12.00%)	1 (4.00%)	21 (84.00%)
Water Asset Manager	2 (8.00%)	2 (8.00%)	21 (84.00%)
Water Control Officer	3 (12.00%)	2 (8.00%)	20 (80.00%)

Water Process Controller (Water Works Management Practitioner)	4 (16.00%)	1 (4.00%)	20 (80.00%)
Water Production and Supply Manager	2 (8.00%)	1 (4.00%)	22 (88.00%)
Water Quality Analyst (Wastewater Treatment Officer/Technician)	5 (20.00%)	1 (4.00%)	19 (76.00%)
Water Quality Analyst (Water Quality Technician)	3 (12.00%)	1 (4.00%)	21 (84.00%)
Other:_____	2 (8.33%)	1 (4.17%)	21 (87.50%)

*Respondents could select both the filled and vacant option and therefore the numbers in the respective rows will not necessarily add to 24.

Occupations relevant to institutions and organisations involved in water-related RDI activities included in this study were Laboratory Technician, Project/Research Manager, R&D Manager, Researcher, and Technology Transfer Officer. Table 6 lists the number of departments in organisations and institutions involved in water-related RDI activities indicating filled and vacant positions for the respective occupations (n = 18). Respondents were also provided with the opportunity to select N/A (not applicable). The occupation Researcher had the highest number of respondents selecting the filled (14 respondents) and vacant (5 respondents) options for their respective departments. Project/Research Manager had 12 and 1 respondents, respectively, selecting the filled and vacant options while R&D Manager had 6 respondents selecting the filled option.

Table 6: The number of departments in organisations and institutions involved in water-related RDI activities indicating filled and vacant positions for the respective occupations (n = 18)*

Occupation	Filled	Vacant	N/A
Laboratory Technician	7 (38.89%)	1 (5.56%)	10 (55.56%)
Project/Research Manager	12 (66.67%)	1 (5.56%)	5 (27.78%)
R&D Manager	6 (33.33%)	1 (5.56%)	11 (61.11%)
Researcher	14 (66.67%)	5 (23.81%)	2 (9.52%)
Technology Transfer Officer	0 (0.00%)	1 (5.56%)	17 (94.44%)
Other	3 (16.67%)	3 (16.67%)	12 (66.67%)

*Respondents could select both the filled and vacant option and therefore the numbers in the respective rows will not necessarily add to 18.

In the questionnaire the same set of skills were represented to the respondents for each of the occupations. Skills matrices were compiled, present in the supplementary data sheets, with the skills (filled, vacant and not applicable) listed for each water-related occupation. For every skill the total number of filled, vacant and not applicable options the respondents selected were added for all the occupations. In other words for the skill “information management” the number of vacancies reported for Agricultural Engineer (Irrigation Engineer), Agricultural Engineering Technologist (Irrigation Engineering Technologist), Agricultural Technician (Irrigation Technician), Chemical Engineer, etc. were added to provide the total number of vacancies listed for “information management”. The same method of data analysis was followed for the questionnaire for the water sector (Table 7) and for the water-related RDI environment (Table 8).

The results show that the top ten skills in demand (the highest number of vacancies reported by the respondents) in the departments of the respective organisations in the water sector are: “using large scale datasets (Big data)” (60 listed); “information management” (56 listed); “GIS and remote sensing” (56 listed); “time management” (55 listed); “understand the internal and external environment” (55

listed); “training” (55 listed); “risk management” (54 listed); “participation in research and development” (54 listed); “sampling and data collection” (54 listed); and “supervision of staff” (54 listed) (Table 7).

Table 7: Skills matrix for the occupations listed in the water sector questionnaire (n = 24)

	TOTAL		
	Filled	**Vacant**	**N/A**
TECHNICAL SKILLS			
Design dams and weirs	39	15	119
Design pipelines	49	20	110
Design pump stations	50	23	108
Design, audit and implement efficient energy and waste management systems	46	21	111
Design, audit, and implement industrial effluent treatment systems	55	27	102
Design, audit, and implement wastewater treatment systems	58	28	99
Design, audit, and implement water treatment systems	57	28	100
Domain Knowledge	86	49	69
Engineering drawings and P&ID	62	28	96
GIS and remote sensing	97	56	54
Implement sustainable mixed farming methods based on land and water management	39	20	116
Implement water stewardship practices	70	37	79
Industrial effluent management	72	34	81
Surface water hydrology	63	28	89
Water demand calculations	68	19	91
Water quality assessment	97	40	54
Water quantity assessment	84	28	69
Water resource management	88	29	63
MANAGEMENT			
Business development	44	7	111
Leadership skills	106	52	46
Management of facilities	74	39	79
Marketing	43	4	113
Monitoring and evaluation of water projects	79	37	71
Procurement management	90	51	65
Supervisory management	108	51	47
Water governance	92	42	63
PLANNING			
Planning of water schemes	73	41	82
Policy making and implementation	71	33	85
Strategic planning	86	34	68
OPERATIONAL			
Community liaison and communication	76	40	73
Design and implementation of monitoring systems	102	51	50
Energy audits	52	25	106

Environmental control	95	48	57
ICT operation and management	63	28	92
O&M management	76	29	82
Operational management	85	33	72
Quality control	110	52	41
Risk management	114	54	38
Self-assessments	112	51	42
Time management	116	55	36
Treatment plant inspections and audits	85	30	74
RESEARCH, DEVELOPMENT, AND INNOVATION/SCIENTIFIC SERVICES			
Conduct research and develop projects	94	50	56
Design and conduct experiments and tests	94	48	58
Development of research projects	89	46	64
Laboratory and pilot-scale work	84	47	68
Laboratory procedures	77	40	74
Laboratory safety	77	40	74
Operate and maintain analytical equipment	70	39	83
Participation in research and development projects	108	54	43
Planning of water sampling programs	90	40	64
Prepare proposals	109	52	43
Prepare scientific papers and reports	105	50	49
Product development	57	26	93
Research ethics	90	50	63
Sampling and data collection	106	54	46
Using large scale datasets (Big data)	91	60	57
TECHNOLOGY AND COMMERCIALIZATION			
Information management	111	56	39
Intellectual Property Rights	76	46	80
New business development	45	8	112
Technology evaluation	96	50	57
Technology validation	90	47	66
Understand the internal and external regulatory environment	103	55	48
FINANCIAL			
Asset management in the water sector	73	35	82
Budget management and control	96	42	60
Costing and cost estimation	84	35	66
Financial management	101	52	52
Tariff setting	62	27	97
HUMAN RESOURCES			
Management of technical teams	81	41	69
Supervision of staff	113	54	39
Training	120	55	34

CONTRACT MANAGEMENT			
Contract management for engineers and scientists	67	29	89
Preparation of tenders and specifications	83	36	69
Tender adjudication	74	33	80
Water Law	87	48	66
OTHER			
Other: Please specify	4	4	156

Classifying the top skills in demand according to their descriptive headings reveals that three of the skills are grouped under the heading Research, Development and Innovation/Scientific Services ["participation in research and development projects", "sampling and data collection" and "using large scale datasets (Big data)"], two under the heading Technology and Commercialisation ("information management" and "understand the internal and external regulatory environment"), two under the heading Human Resources ("supervision of staff" and "training") and one under the heading Technical Skills ("GIS and remote sensing").

The results further indicate that the skills lowest in demand (the lowest number of vacancies reported by the respondents) in the departments of the organisations or institutions involved in water-related RDI activities of the respondents are: "marketing" (4 listed); "business development" (7 listed); "new business development" (8 listed); and "design dams and weirs" (15 listed).

The results show that the top ten skills in demand (the highest number of vacancies reported by the respondents) in the departments of the respective organisations or institutions involved in water-related RDI activities are: "risk management" (22 listed); "visioning" (20 listed); "information management" (19 listed); "new business development" (18 listed); "social astuteness" (18 listed); "understand the internal and external regulatory environment" (18 listed); "dissemination and exploitation of research outcomes" (17 listed); "networking ability" (17 listed); "understand the business environment in which the company operates" (17 listed) with "commercial awareness", "emotional intelligence", "integration", "leadership skills" and "using large scale datasets (Big Data)" all at position ten with 16 vacancies listed each (Table 8).

Classifying the top skills in demand according to their descriptive headings reveals that six of the skills are grouped under the heading Management ("visioning", "social astuteness", "networking ability", "emotional intelligence", "integration", and "leadership skills"), four under the heading Technology and Commercialisation ("new business development", "understand the internal and external regulatory environment", "understand the business environment in which the company operates", and "commercial awareness"), and three under the heading Research, Development and Innovation/Scientific Services ("information management", "dissemination and exploitation of research outcomes", and "using large scale datasets").

The results further indicate that the skills lowest in demand (the lowest number of vacancies reported by the respondents) in the departments of the organisations or institutions involved in water-related RDI activities of the respondents are: "understanding/applying a range of methods and tools" (0 listings); "prepare for laboratory tasks using the appropriate scientific techniques" (5 listings); "work safely in a laboratory" (5 listings); "perform laboratory tasks following specified methodologies" (6 listings); and "technical competence in the use of specified instruments and laboratory equipment" (6 listings).
The skills filled, vacant and not applicable for each water-related occupation are in the supplementary data sheets.

Table 8: Skills matrix for the occupations listed in the water-related RDI questionnaire (n = 18)

	TOTAL		
	Filled	**Vacant**	**N/A**
TECHNICAL SKILLS			
Computing skills	38	10	2
Numeracy skills	36	10	4
Presentation and communication skills	39	9	3
Teaching skills	27	10	13
Written communication skills	41	9	1
MANAGEMENT			
Adaptability	31	15	5
Decision making	33	13	5
Emotional intelligence	29	16	6
Integration	30	16	5
Interpersonal skills	38	11	2
Leadership skills	26	16	9
Negotiating	22	15	14
Networking ability	28	17	6
Scheduling	34	9	8
Scoping	28	12	11
Social astuteness	25	18	8
Team working	36	14	1
Time management	38	12	1
Visioning	23	20	8
OPERATIONAL			
Management of project and resources	37	10	4
Risk management	20	22	9
RESEARCH, DEVELOPMENT AND INNOVATION/SCIENTIFIC SERVICES			
Collection of qualitative data	33	8	9
Collection of quantitative data	36	9	5
Development of critical thinking skills	31	15	5
Development of theoretical concepts	35	8	8
Dissemination and exploitation of research outcomes	28	17	6
Domain knowledge	31	12	8
Formulation of research problems	27	12	12
Information management	27	19	5
Interpretation and presentation of qualitative data	33	9	9
Interpretation and presentation of quantitative data	36	9	6
Keep accurate records of laboratory work undertaken and results	24	7	20
Multidisciplinary research-coordination	26	11	14
Perform laboratory tasks following specified methodologies	22	6	23
Prepare for laboratory tasks using the appropriate scientific techniques	21	5	25
Procurement management	22	12	17
Produce reliable, accurate data	38	7	5
Quality management	32	12	7

Recognize problems and apply appropriate methods to identify causes and achieve solutions	35	11	4
Research ethics	31	15	5
Technical competence in the use of specified instruments and laboratory equipment	30	6	15
Understand and follow quality procedures	28	15	8
Understanding/applying a range of methods and tools	50	0	0
Use of bibliographic sources and methods	34	14	3
Using large scale datasets	23	16	10
Work safely in a laboratory	24	5	21
TECHNOLOGY AND COMMERCIALISATION			
Commercial awareness	20	16	15
Intellectual Property Rights	21	13	16
Knowledge of intellectual property rights	24	15	12
New business development	14	18	19
Understand the business environment in which the company operates	22	17	11
Understand the internal and external regulatory environment	26	18	7
FINANCIAL			
Budgeting	32	10	9
HUMAN RESOURCES			
Participate in continuous performance improvement	35	12	3
CONTRACT MANAGEMENT			
Document and contract administration	28	10	13

4.2.2 Vacancies

Respondents completing the questionnaire were requested to indicate the occupations which are currently vacant in their organisation of employment. The questionnaire was programmed in such a manner that all the occupations which were selected as vacant were listed in a subsequent question which requested the respondents to indicate the reasons for the respective vacancies. The respondents could select more than one reason from the list of options provided.

As stated earlier, the occupation with the most respondents (3) indicating a vacant position in their organisation is Data Management Manager (Data Processing Manager or Data Operations Manager). Reasons for the vacancies were selected as: “economic climate” (2 respondents); “slow recruitment process” (2 respondents); “candidates not registered with professional body” (1 respondent); “lack of experience” (1 respondent); “lack of qualifications” (1 respondent); “poor remuneration” (1 respondent); and “unsuitable job location” (1 respondent).

Overall, with the exception of Local Authority Manager (Water Services Manager), one or more respondents indicated that the reasons for vacancies for each of the occupations were: “candidates not registered with professional body”; “economic climate”; “lack of experience”; “lack of qualifications”; “poor remuneration”; “slow recruitment process”; and “unsuitable job location”. “New or emerging job” was only selected as the reason for a vacancy for the occupations Chemist, Civil Engineering Technologist (Water and Wastewater Technologist), Communication Coordinator (Water Liaison Practitioner), Environmental Engineer (Water Resource Specialist), Environmental Manager (Sanitation Programme Manager), Environmental Manager (Water Resource Management Practitioner), Environmental Manager (Water Resource Manager), Environmental Scientist (Water Use Specialist)

and Water Asset Manager, while none of the respondents selected “unsuitable working hours” (not included in the table) as a reason for a vacancy (Table 9).

In research units of organisations and institutions involved in water-related RDI activities, the occupation with the highest number of departments reporting vacancies were Researchers with four research units reporting vacancies in the post (Table 10). Reasons for the vacancies were selected as: “economic climate” (3 respondents); “lack of relevant experience” (2 respondents); “lack of qualifications” (1 respondent); “new or emerging job” (1 respondent); and “slow recruitment process” (1 respondent). Laboratory Technician, Project/Research Manager, R&D Manager and Technology Transfer Officer were each selected as vacant by one respondent, respectively. None of the respondents selected the: “candidates are not registered with professional body”; “unsuitable job location”; and “unsuitable working hours” as reasons for vacancies (not included in the table).

Table 9: The reasons for the vacancies for the occupations in the water sector questionnaire (n = 8)*

Occupation	Vacant	Reasons for vacancies							
		Candidates not registered with PB	Economic climate	Lack of experience	Lack of qualifi-cations	New or emerging job	Poor remune-ration	Slow recruitment process	Unsuitable job location
Agricultural Engineer (Irrigation Engineer)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Agricultural Engineering Technologist (Irrigation Engineering Technologist)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Agricultural Technician (Irrigation Technician)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Chemical Engineer	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Chemical Engineering Technician	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Chemical Engineering Technologist (Environmental (Water, Air, Soil) Technologist)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Chemist	2	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)
Civil Engineer (Construction Engineer)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Civil Engineer (Hydraulics Engineer)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Civil Engineer (Water and Wastewater Engineer)	2	2 (22.22%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	-	2 (22.22%)	1 (11.11%)	1 (11.11%)
Civil Engineering Technician	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Civil Engineering Technologist (Construction Technologist)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Civil Engineering Technologist (Hydraulics Technologist)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Civil Engineering Technologist (Water and Wastewater Technologist)	2	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)
Communication Coordinator (Water Liaison Practitioner)	1	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)

Data Management Manager (Data Processing Manager or Data Operations Manager)	3	1 (11.11%)	2 (22.22%)	1 (11.11%)	1 (11.11%)	-	1 (11.11%)	2 (22.22%)	1 (11.11%)
Electrical Engineer	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Electrical Engineering Technologist	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Electronic Engineering Technician (Instrumentation Technician or Telemetry Technician)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Engineering Manager (Engineering Maintenance Manager)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Environmental Engineer (Water Resource Specialist)	1	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)
Environmental Manager (Sanitation Programme Manager)	1	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)
Environmental Manager (Water Resource Management Practitioner)	2	1 (11.11%)	2 (22.22%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	1 (11.11%)
Environmental Manager (Water Resource Manager)	1	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)
Environmental Science Technician (Environmental Technical Officer)	2	1 (12.50%)	2 (25.00%)	1 (12.50%)	1 (12.50%)	-	1 (12.50%)	1 (12.50%)	1 (12.50%)
Environmental Science Technician (Water Pollution Control Officer)	2	1 (12.50%)	2 (25.00%)	1 (12.50%)	1 (12.50%)	-	1 (12.50%)	1 (12.50%)	1 (12.50%)
Environmental Scientist (Environmental Officer)	2	1 (12.50%)	2 (25.00%)	1 (12.50%)	1 (12.50%)	-	1 (12.50%)	1 (12.50%)	1 (12.50%)
Environmental Scientist (Environmental Research Scientist)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Environmental Scientist (Water Use Specialist)	2	1 (11.11%)	2 (22.22%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	1 (11.11%)
Geologist (Hydrogeologist)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
GIS Technician (GIS Operator/Specialist)	2	1 (12.50%)	2 (25.00%)	1 (12.50%)	1 (12.50%)	-	1 (12.50%)	1 (12.50%)	1 (12.50%)
Hydrologist	2	1 (10.00%)	2 (20.00%)	2 (20.00%)	2 (20.00%)	-	1 (10.00%)	1 (10.00%)	1 (10.00%)
Local Authority Manager (Water Services Provider Manager)	-	-	-	-	-	-	-	-	-

Mechanical Engineer (Mechatronics Engineer)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Mechanical Engineering Technician	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Mechanical Engineering Technologist (Maintenance Technologist)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Microbiologist	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Programme or Project Manager	2	1 (12.50%)	2 (25.00%)	1 (12.50%)	1 (12.50%)	-	1 (12.50%)	1 (12.50%)	1 (12.50%)
Surveyor	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Water Asset Manager	2	1 (11.11%)	2 (22.22%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	1 (11.11%)
Water Control Officer	2	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	-	1 (12.50%)	2 (25.00%)	1 (12.50%)
Water Process Controller (Water Works Management Practitioner)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Water Production and Supply Manager	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Water Quality Analyst (Wastewater Treatment Officer/Technician)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Water Quality Analyst (Water Quality Technician)	1	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	-	1 (14.29%)	1 (14.29%)	1 (14.29%)
Other: Please specify	1	-	1 (100.00%)	-	-	-	-	-	-

* The respondents could select more than one reason from the list of options provided.

Table 10: The reasons for the vacancies for the occupations in the water-related RDI questionnaire (n = 8)*

Occupation	Vacancies	Reasons for vacancies					
		Economic climate	Lack of experience	Lack of qualifi-cations	New or emerging job	Poor remune-ration	Slow recruitment process
Laboratory Technician	1	1 (50.00%)	-	-	1 (50.00%)	-	-
Project/-Research Manager	1	-	-	-	-	-	1 (100.00%)
R&D Manager	1	1 (100.00%)	-	-	-	-	-
Researcher	5	3 (37.50%)	2 (25.00%)	1 (12.50%)	1 (12.50%)	-	1 (12.50%)
Technology Transfer Officer	1	1 (50.00%)	-	-	1 (50.00%)	-	-
Other	3	1 (25.00%)	1	-	1 (25.00%)	1 (25.00%)	-

* The respondents could select more than one reason from the list of options provided.

4.2.3 High Staff Turnover Rate

Respondents completing the questionnaire were also requested to indicate the occupations which have a high staff turnover rate in their organisation of employment. The questionnaire was programmed in such a manner that all the occupations which were selected as filled, vacant or both were listed in a subsequent question which requested the respondents to indicate if the respective occupations experiences high staff turnover rates. The respondents could select more than one reason from the list of options provided.

The only occupation which was not selected by respondents as experiencing a high staff turnover rate was Local Authority Manager (Water Services Provider Manager). One or more respondents indicated that the reasons for the high staff turnover rates for the other occupations, with the exception of Water Quality Analyst (Water Quality Technician), included: “contract closure”; “dismissals”; “economic climate”; “resignations”; and “retirement”. Reasons for high staff turnover rates for Water Quality Analyst (Water Quality Technician) included: “contract closure”; “dismissals”; “economic climate”; and “retirement” (Table 11).

Table 11: The reasons for the high staff turnover rate for the occupations in the water sector questionnaire (n = 19)*

Occupation	Filled, vacant or both	N/A	Reasons for high staff turnover rate				
			Contract closure	Dismissals	Economic climate	Resigna-tions	Retirement
Agricultural Engineer (Irrigation Engineer)	2	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)
Agricultural Engineering Technologist (Irrigation Engineering Technologist)	2	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)
Agricultural Technician (Irrigation Technician)	3	2 (28.57%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)
Chemical Engineer	3	2 (28.57%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)
Chemical Engineering Technician	3	1 (14.29%)	2 (28.57%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)

Chemical Engineering Technologist (Environmental (Water, Air, Soil) Technologist)	2	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)
Chemist	5	3 (33.33%)	1 (11.11%)	1 (11.11%)	2 (22.22%)	1 (11.11%)	1 (11.11%)
Civil Engineer (Construction Engineer)	1	-	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)
Civil Engineer (Hydraulics Engineer)	2	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)
Civil Engineer (Water and Wastewater Engineer)	4	3 (37.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)
Civil Engineering Technician	4	3 (37.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)
Civil Engineering Technologist (Construction Technologist)	2	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)
Civil Engineering Technologist (Hydraulics Technologist)	1	-	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)
Civil Engineering Technologist (Water and Wastewater Technologist)	6	4 (40.00%)	1 (10.00%)	1 (10.00%)	2 (20.00%)	1 (10.00%)	1 (10.00%)
Communication Coordinator (Water Liaison Practitioner)	5	4 (44.44%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	1 (11.11%)	1 (11.11%)
Data Management Manager (Data Processing Manager or Data Operations Manager)	6	4 (40.00%)	1 (10.00%)	1 (10.00%)	2 (20.00%)	1 (10.00%)	1 (10.00%)
Electrical Engineer	2	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)
Electrical Engineering Technologist	1	-	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)
Electronic Engineering Technician (Instrumentation Technician or Telemetry Technician)	1	-	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)
Engineering Manager (Engineering Maintenance Manager)	1	-	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)
Environmental Engineer (Water Resource Specialist)	3	2 (28.57%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)
Environmental Manager (Sanitation Programme Manager)	3	2 (28.57%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)
Environmental Manager (Water Resource Management Practitioner)	5	2 (22.22%)	1 (11.11%)	1 (11.11%)	2 (22.22%)	2 (22.22%)	1 (11.11%)

Environmental Manager (Water Resource Manager)	5	3 (33.33%)	1 (11.11%)	1 (11.11%)	2 (22.22%)	1 (11.11%)	1 (11.11%)
Environmental Science Technician (Environmental Technical Officer)	5	3 (33.33%)	1 (11.11%)	1 (11.11%)	2 (22.22%)	1 (11.11%)	1 (11.11%)
Environmental Science Technician (Water Pollution Control Officer)	6	3 (30.00%)	1 (10.00%)	1 (10.00%)	2 (20.00%)	2 (20.00%)	1 (10.00%)
Environmental Scientist (Environmental Officer)	6	2 (20.00%)	1 (10.00%)	1 (10.00%)	3 (30.00%)	2 (20.00%)	1 (10.00%)
Environmental Scientist (Environmental Research Scientist)	5	3 (33.33%)	1 (11.11%)	1 (11.11%)	2 (22.22%)	1 (11.11%)	1 (11.11%)
Environmental Scientist (Water Use Specialist)	4	2 (25.00%)	1 (12.50%)	1 (12.50%)	2 (25.00%)	1 (12.50%)	1 (12.50%)
Geologist (Hydrogeologist)	4	1 (11.11%)	1 (11.11%)	1 (11.11%)	3 (33.33%)	1 (11.11%)	2 (22.22%)
GIS Technician (GIS Operator/Specialist)	9	4 (30.77%)	1 (7.69%)	1 (7.69%)	2 (15.38%)	3 (23.08%)	2 (15.38%)
Hydrologist	4	2 (25.00%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	2 (25.00%)
Local Authority Manager (Water Services Provider Manager)	2	2 (100.00%)	-	-	-	-	-
Mechanical Engineer (Mechatronics Engineer)	2	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)
Mechanical Engineering Technician	1	-	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)
Mechanical Engineering Technologist (Maintenance Technologist)	3	2 (28.57%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)
Microbiologist	6	3 (30.00%)	1 (10.00%)	1 (10.00%)	2 (20.00%)	2 (20.00%)	1 (10.00%)
Programme or Project Manager	6	3 (27.27%)	1 (9.09%)	1 (9.09%)	3 (27.27%)	2 (18.18%)	1 (9.09%)
Surveyor	3	2 (28.57%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)
Water Asset Manager	3	2 (28.57%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)	1 (14.29%)
Water Control Officer	4	3 (37.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)	1 (12.50%)
Water Process Controller (Water Works Management Practitioner)	4	1 (12.50%)	1 (12.50%)	1 (12.50%)	2 (25.00%)	2 (25.00%)	1 (12.50%)
Water Production and Supply Manager	2	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	1 (16.67%)
Water Quality Analyst (Wastewater Treatment Officer/Technician)	5	3 (33.33%)	1 (11.11%)	1 (11.11%)	2 (22.22%)	1 (11.11%)	1 (11.11%)
Water Quality Analyst (Water Quality Technician)	3	2 (33.33%)	1 (16.67%)	1 (16.67%)	1 (16.67%)	-	1 (16.67%)
Other:_____	3	-	-	1 (33.33%)	-	-	2 (66.67%)

* The respondents could select more than one reason from the list of options provided.

In departments of organisations and institutions involved in water-related RDI activities, the occupation with the highest number of departments reporting a high staff turnover rate were Researchers with nine research units reporting high staff turnover rates for the occupation (Table 12). Reasons for the vacancies were selected as: “resignations” (5 respondents); “contract closure” (4 respondents); and “economic climate” (1 respondent). Six departments reported a high staff turnover rate for Project/Research Managers with “contract closure” (4 respondents) and “resignations” (2 respondents) selected as the reasons.

Table 12: The reasons for the high staff turnover rate for the occupations in the water-related RDI questionnaire (n = 17)*

Occupation	Filled, vacant or both	N/A	Reasons for high staff turnover rate				
			Contract closure	Dismissals	Economic climate	Resignations	Retirement
Laboratory Technician	8	5 (62.50%)	1 (12.50%)	-	-	2 (25.00%)	-
Project/Research Manager	13	7 (53.85%)	4 (30.77%)	-	-	2 (15.38%)	-
R&D Manager	7	4 (57.14%)	2 (28.57%)	-	1 (14.29%)	-	-
Researcher	16	7 (41.18%)	4 (23.53%)	-	1 (5.88%)	5 (29.41%)	-
Technology Transfer Officer	1	1 (100%)	-	-	-	-	-
Other	6	3 (50%)	-	-	1 (16.67) (20.00%)	1 (16.67%)	1 (16.67%)

* The respondents could select more than one reason from the list of options provided.

4.2.4 Upskilling and/or Reskilling of Current Employees

Respondents completing the questionnaire were requested to indicate the occupations which require the reskilling and/or upskilling of current employees in their organisation of employment. The questionnaire was programmed in such a manner that all the occupations which were selected as filled were listed in a subsequent question which requested the respondents to indicate which learning interventions, if applicable, are applied for the respective occupations. The respondents could select more than one reason from the list options provided.

As stated earlier the occupation with the most respondents (8) indicating a filled position in the department of their organisation is GIS Technician (GIS Operator/Specialist). Learning interventions identified for GIS Technician included: “short courses” (6 respondents); “workplace learning” (6 respondents); “formal qualification” (2 respondents); and “professional registration with CPD” (2 respondents). Microbiologist had 6 respondents indicating filled positions within the department of their organisations of employment. Learning interventions identified for Microbiologists included: “short courses” (4 respondents), “workplace learning” (4 respondents), “formal qualification” (3 respondents) and “professional registration and CPD” (3 respondents). Overall, with the exception of Local Authority Manager (Water Services Manager), the respondents indicated that all four interventions are applied to the water-related occupations included in the study. Respondents indicated that Professional registration and CPD as well as Workplace mentoring are the two learning interventions for the occupation Local Authority Manager (Table 13).

Table 13: Learning interventions for the occupations in the water sector questionnaire (n = 18)*

Occupation	Filled	Learning interventions

		N/A	Formal qualification	Professional registration and CPD	Short courses	Workplace learning (Mentoring system)
Agricultural Engineer (Irrigation Engineer)	2	-	2 (25.00%)	2 (25.00%)	2 (25.00%)	2 (25.00%)
Agricultural Engineering Technologist (Irrigation Engineering Technologist)	2	-	2 (25.00%)	2 (25.00%)	2 (25.00%)	2 (25.00%)
Agricultural Technician (Irrigation Technician)	3	1 (11.11%)	2 (22.22%)	2 (22.22%)	2 (22.22%)	2 (22.22%)
Chemical Engineer	3	1 (14.29%)	2 (28.57%)	1 (14.29%)	2 (28.57%)	1 (14.29%)
Chemical Engineering Technician	3	-	2 (28.57%)	1 (14.29%)	2 (28.57%)	2 (28.57%)
Chemical Engineering Technologist (Environmental (Water, Air, Soil) Technologist)	2	-	2 (25.00%)	2 (25.00%)	2 (25.00%)	2 (25.00%)
Chemist	4	-	1 (12.50%)	1 (12.50%)	4 (50.00%)	2 (25.00%)
Civil Engineer (Construction Engineer)	1	-	1 (25.00%)	1 (25.00%)	1 (25.00%)	1 (25.00%)
Civil Engineer (Hydraulics Engineer)	2	-	2 (25.00%)	2 (25.00%)	2 (25.00%)	2 (25.00%)
Civil Engineer (Water and Wastewater Engineer)	3	-	1 (16.67%)	3 (50.00%)	1 (16.67%)	1 (16.67%)
Civil Engineering Technician	4	-	1 (12.50%)	3 (37.50%)	2 (25.00%)	2 (25.00%)
Civil Engineering Technologist (Construction Technologist)	2	-	1 (20.00%)	2 (40.00%)	1 (20.00%)	1 (20.00%)
Civil Engineering Technologist (Hydraulics Technologist)	1	-	1 (25.00%)	1 (25.00%)	1 (25.00%)	1 (25.00%)
Civil Engineering Technologist (Water and Wastewater Technologist)	5	-	2 (18.18%)	5 (45.45%)	2 (18.18%)	2 (18.18%)
Communication Coordinator (Water Liaison Practitioner)	5	1 (8.33%)	3 (25.00%)	2 (16.67%)	4 (33.33%)	2 (16.67%)
Data Management Manager (Data Processing Manager or Data Operations Manager)	4	1 (10.00%)	2 (20.00%)	2 (20.00%)	3 (30.00%)	2 (20.00%)
Electrical Engineer	2	-	2 (33.33%)	1 (16.67%)	2 (33.33%)	1 (16.67%)
Electrical Engineering Technologist	1	-	1 (25.00%)	1 (25.00%)	1 (25.00%)	1 (25.00%)
Electronic Engineering Technician (Instrumentation Technician or Telemetry Technician)	1	-	1 (25.00%)	1 (25.00%)	1 (25.00%)	1 (25.00%)

Engineering Manager (Engineering Maintenance Manager)	1	-	1 (25.00%)	1 (25.00%)	1 (25.00%)	1 (25.00%)
Environmental Engineer (Water Resource Specialist)	3	-	3 (30.00%)	3 (30.00%)	2 (20.00%)	2 (20.00%)
Environmental Manager (Sanitation Programme Manager)	3	1 (11.11%)	2 (22.22%)	2 (22.22%)	2 (22.22%)	2 (22.22%)
Environmental Manager (Water Resource Management Practitioner)	4	-	3 (23.08%)	3 (23.08%)	4 (30.77%)	3 (23.08%)
Environmental Manager (Water Resource Manager)	5	1 (7.69%)	3 (23.08%)	3 (23.08%)	3 (23.08%)	3 (23.08%)
Environmental Science Technician (Environmental Technical Officer)	4	-	2 (20.00%)	2 (20.00%)	4 (40.00%)	2 (20.00%)
Environmental Science Technician (Water Pollution Control Officer)	5	-	3 (23.08%)	2 (15.38%)	5 (38.46%)	3 (23.08%)
Environmental Scientist (Environmental Officer)	5	-	4 (33.33%)	2 (16.67%)	3 (25.00%)	3 (25.00%)
Environmental Scientist (Environmental Research Scientist)	5	1 (7.69%)	3 (23.08%)	3 (23.08%)	3 (23.08%)	3 (23.08%)
Environmental Scientist (Water Use Specialist)	3	-	3 (27.27%)	2 (18.18%)	3 (27.27%)	3 (27.27%)
Geologist (Hydrogeologist)	4	-	3 (33.33%)	2 (22.22%)	2 (22.22%)	2 (22.22%)
GIS Technician (GIS Operator/Specialist)	8	-	2 (12.50%)	2 (12.50%)	6 (37.50%)	6 (37.50%)
Hydrologist	3	-	3 (42.86%)	2 (28.57%)	1 (14.29%)	1 (14.29%)
Local Authority Manager (Water Services Provider Manager)	2	-	-	1 (50.00%)	-	1 (50.00%)
Mechanical Engineer (Mechatronics Engineer)	2	-	1 (16.67%)	1 (16.67%)	2 (33.33%)	2 (33.33%)
Mechanical Engineering Technician	1	-	1 (25.00%)	1 (25.00%)	1 (25.00%)	1 (25.00%)
Mechanical Engineering Technologist (Maintenance Technologist)	3	-	2 (20.00%)	2 (20.00%)	3 (30.00%)	3 (30.00%)
Microbiologist	6	2 (12.50%)	3 (18.75%)	3 (18.75%)	4 (25.00%)	4 (25.00%)
Programme or Project Manager	5	-	2 (15.38%)	3 (23.08%)	3 (23.08%)	5 (38.46%)
Surveyor	3	-	2 (22.22%)	2 (22.22%)	3 (33.33%)	2 (22.22%)
Water Asset Manager	2	-	2 (25.00%)	2 (25.00%)	2 (25.00%)	2 (25.00%)
Water Control Officer	3	-	2 (22.22%)	2 (22.22%)	3 (33.33%)	2 (22.22%)
Water Process Controller (Water Works Management Practitioner)	4	-	2 (18.18%)	2 (18.18%)	4 (36.36%)	3 (27.27%)

Water Production and Supply Manager	2	-	2 (25.00%)	2 (25.00%)	2 (25.00%)	2 (25.00%)
Water Quality Analyst (Wastewater Treatment Officer/Technician)	5	-	3 (25.00%)	2 (16.67%)	5 (41.67%)	2 (16.67%)
Water Quality Analyst (Water Quality Technician)	3	-	2 (22.22%)	2 (22.22%)	3 (33.33%)	2 (22.22%)
Other:_____	2	2 (100.00%)	-	-	-	-

* The respondents could select more than one learning intervention from the list of options provided.

"Formal qualification" was selected by 10 respondents as a learning intervention for Researchers, by 5 respondents as a learning intervention for Project/Research Manager and by 4 and 3 respondents for R&D Manager and Laboratory Technician, respectively. Eight respondents selected "professional registration and CPD" as a learning intervention for Project/Research Manager, while 6 and 5 respondents selected this option as a learning intervention for Researcher and R&D Manager (Table 14). Eleven respondents selected "short courses" as a learning intervention for Researchers while 10 respondents selected this option as a learning intervention for Project/Research Manager. "Workplace learning (mentoring system)" was selected by 9 respondents each as a learning intervention for Project/Research Manager and Researcher. No learning interventions could be identified for Technology Transfer Officer as none of the respondents selected the occupation as filled within their organisation of employment.

Table 14: Learning interventions for the occupations in water-related RDI questionnaire (n = 17).*

			Learning intervention			
Occupation	**Filled**	**N/A**	Formal qualification	Professional registration and CPD	Short courses	Workplace learning (Mentoring system)
Laboratory Technician	7	-	3 (20.00%)	1 (6.67%)	5 (33.33%)	6 (40.00%)
Project/Research Manager	11	-	5 (15.63%)	8 (25.00%)	10 (31.25%)	9 (28.13%)
R&D Manager	6	1 (6.25%)	4 (25.00%)	5 (31.25%)	4 (25.00%)	2 (12.50%)
Researcher	14	1 (2.70%)	10 (27.03%)	6 (16.22%)	11 (29.73)	9 (24.32%)
Technology Transfer Officer	0	-	-	-	-	-
Other	2	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)	1 (20.00%)

* The respondents could select more than one learning intervention from the list of options provided.

4.3 FOCUS GROUPS

Focus groups were conducted with various role players in industries with ties to the water sector to gain a better understanding of skills demand and development in the water sector. Thirty-two individuals representing nine sectors (agricultural; CMAs; consultancy and engineering; RDI sector; industrial sector; mining; municipalities; national or provincial government; water boards or utilities) participated in the respective focus groups (n = 13) or provided written feedback in cases where they were unable to attend the sessions. A participation rate of 44.7% from the total invited participants (n = 67) was obtained. The focus group sessions entailed a description of the current project (background information), an overview of the themes that needed to be discussed, followed by an open discussion

by the participants. The main discussion points from each session were then summarised and compiled into the three themes, viz. (1) occupations and skills, (2) graduate and postgraduate skills demand in the water sector, and (3) addressing skills gaps in the water sector.

4.3.1 Occupations and skills

Overall, many organisations indicated that they have vacant positions and that required major skills are often lacking.

For the CMAs, the major lack in skills is often associated with technical positions such as geohydrologists, freshwater ecologists and positions in the compliance section of the organisation. The lack of skills does not pertain to the qualifications that applicants for the available positions have, but is mostly related to job experience. The organisations do not always have the capacity to train young professionals in the positions that they may be appointed in and therefore seek individuals with the relevant work experience to fill available positions to facilitate easy integration of new employees into the organisations. Additionally, currently available positions include engineering and geohydrology occupations. These positions become vacant as employees move to better positions or they relocate to major cities. The major problem is that these positions often remain vacant for extended periods of time because of the job requirements (job experience being essential), the scarcity of professionals adhering to all the requirements and late submission of applications.

From an engineering/consultancy perspective, it was noted by the participants that the quality of young graduates entering the job market has improved over the last 10 years, as they display a good technical skill set (theoretical knowledge). However, it was highlighted that the skills quality of the young graduates was dependent on their education background, as graduates from technical colleges (e.g. TVET colleges or Universities of Technology) generally require more training (e.g. mentorship and training programs) to succeed in the private sector. Senior civil engineer and hydrologist (catchment level planning) positions were identified as the dominant vacancies within the water sector. It was noted by the participants that there has been more stability in the engineering/consultancy sector with regards to high staff turnover rates associated with job-hopping, as individuals generally tend to stay in their organisations unless they want a significant career focus shift or if they are young professionals seeking better opportunities (more senior positions). However, this may be organisation dependent (e.g. environment within the organisation, intellectual stimulation, available opportunities). Additionally, it was outlined that while consultants may struggle to generate work within South Africa, many of them are finding work from outside of South Africa.

In the RDI sector, the ability to take science to society and thus bridge the gap between conducting research and implementing technology within communities, was identified as the major skills gap. Additionally, it was highlighted that the handling, managing, storing, and effective interpretation of large data sets, remains a challenge and professionals and systems to address this issue is thus in high demand. Furthermore, social sciences and expertise in navigating/understanding socio-ecological-systems within the water sector are limited and as such, impede the implementation of new technologies within the water sector.

In the industrial sector, a diverse range of water-related occupations are performed within organisations, as water-related skills are integral to many organisations to efficiently perform their core functions. Additionally, it was noted that organisations within the industrial sector are more likely to employee graduates/postgraduates with specific expertise/specialist training in the various nodes that make up the organisation (organisational units), and as such do not necessarily struggle with addressing potential skills gaps. For example, to address a lack of major skills in a specialist field, the organisations

could recruit individuals with postgraduate experience working on the specific research topic (head-hunted) or the organisation could fund research projects related to the specific problem. The participants also emphasised that organisations within the industrial sector are less likely to be challenged with regards to vacancies or positions that experience a high staff turnover rate due to competition from the external market. However, when organisations restructure, the number of vacancies or staff turnover rate may be influenced. In contrast, vendors (equipment or consumable providers) within the industrial sector do experience higher staff turnover rates; however, these individuals tend to move to a different company within the same field, so the knowledge is not necessarily lost to the sector.

In the mining industry, it was noted that there are rarely dedicated positions for water experts. A major lack of skills has thus been identified in terms of water balance management. Metallurgic engineers, geohydrologists and consultants are often used to fulfil this function, but there is a need to employ professionals in this regard that are unbiased and independent of the government and can manage the water balance for mines specifically.

From the municipalities' perspective, the experience level of interns or young graduates entering municipalities with either a total lack of practical experience or minimal exposure to the practical aspects of the job requirement (including water-related occupations) is a significant concern for providing good quality service. In contrast to the private sector, high staff turnover rates are an issue within municipalities as individuals are prone to leave after a couple of months of gaining practical experience, for a career in the private sector, with positions in the technical departments (e.g. water quality monitoring) experiencing the highest turnover rates. Additionally, due to discrepancies in the applied salary scales between municipalities (local, district and metro municipalities) for the same position, employees may move between municipalities for better financial opportunities. There is thus limited sustainability of individuals gaining experience and working from the ground level up which compounds the problem associated with the lack of practical experience. In some municipalities, it was noted that up to 50% of the positions are vacant, which also affects good service delivery. The vacancies were mostly attributable to budget constraints and difficulty in attracting qualified individuals to a career in the municipality (suitably qualified/skilled individuals are difficult to afford in comparison to the private sector). Additionally, the legislation/regulations/policies (e.g. equity targets) surrounding the appointment of new employees also contribute to the difficulty of filling the current vacancies within municipalities. Depending on the vacancy, employees may be rotated or required to perform extra tasks to counteract the potential shortfall [e.g. seven chief engineers (depot managers) rotated amongst nine depots to counteract the two current vacancies]; however, the lack of continuity may affect work morale and service efficiency. Internal promotion (e.g. assistant process controller to process controller to senior process controller) of suitably qualified individuals was identified as a way in which to fill more senior vacancies in municipalities, as it is easier to appoint individuals in entry level positions. Lastly, it was outlined that the "requirements" for vacant positions be reassessed to ensure that they align with the job description or core task the employee is expected to complete. For example, it was outlined that vacant positions may be advertised with numerous requirements; however, not all of the listed requirements may be essential for the individual to complete the core day-to-day tasks required from that position, and as such may be preventing the appointment of individuals in these vacancies.

For provincial and national government, it was noted that there is often a mismatch of skills versus positions available. It is believed that in South Africa we have appropriately qualified professionals that can fill the necessary positions and graduates often fare well within government organisations. However, individuals are not always appointed in positions where their skills are most required/fitting. Additionally, government organisations currently experience a major gap between young, qualified professionals entering the organisations and older established employees. The middle group of employees who can mentor, train, teach and develop young professionals to eventually fill senior

positions are missing. There is thus not a lack of specific skills, but a lack of internal structures to capitalise on talent and skills entering governmental organisations. In terms of water-related occupations and positions available within provincial and national government, engineering positions frequently become available. Specifically, engineers (and other professionals) leave government organisations to pursue careers within the private sector and only later return to government organisations (which happens quite often). Other vacancies within the organisations that are available are mostly senior positions. Entry level positions are easily filled with young professionals and graduates (usually there are more young professionals and graduates available to hire, while positions to fill are limited), however senior positions are difficult to fill and often remain vacant for some time. This has been attributed to the strict job requirements (professional registrations and years of experience) stipulated for these positions which hamper individuals progressing to senior positions within the organisation or limits the candidates that can be hired from outside the organisation.

Focus groups with employees of water boards or utilities indicated that skills gaps are organisation dependent. For example, it was outlined that professional engineers (i.e. civil, mechanical, electrical and chemical) and professional technologists were the major gaps identified within the organisation during a previous skills gap assessment; however, while certain water boards reported that these gaps have been addressed by recruiting candidates for water boards or utilities, others have indicated that they still lack civil and chemical engineers. Additionally, appropriately qualified project managers (of large infrastructure projects that aim to service underdeveloped areas) are still lacking. These water boards thus have an over-reliance on consultancy agencies and do not necessarily have the skill set to monitor the work provided by vendors/service providers. Overall, no persistent vacancies or high staff turnover rates were identified within the organisations (employees are normally trained internally and promoted to available positions) as employees tend to stay within their positions.

4.3.2 Graduate and postgraduate skills demand in the water sector

Overall, most of the organisations in the water sector employ Bachelors, Honours and Masters graduates, with doctoral candidates less frequently employed as these professionals tend to go into research specific fields.

In the agricultural sector, it was outlined by the participants that graduates with different qualification levels are employed; however, these qualifications are not necessarily directly water-related, but would rather be qualifications where the graduate was exposed to certain water-related aspects during their studies (e.g. soil scientists). Overall, the lack of practical experience displayed by graduates/postgraduates entering the job market was consistently highlighted as a major concern within the sector. Additionally, the participants noted that there is increasing pressure from their receiving markets about the quality and safety of produce due to water quality. The monitoring and management of water systems and the implementation of water savings techniques/implementation of green technologies was identified as crucial aspects that need to be addressed in the future. The implementation of practical semesters as part of graduate training programs was identified as the most effective way the current skills gap within the sector may be rectified, while exposure of graduates to the policies and legislation surrounding water usage and compliance monitoring was also identified as knowledge that is missing/lacking in the sector.

For CMAs, graduates with bachelor degrees in geohydrology and engineering are sought after, although these agencies also employ geologists and ecologists. Graduates with a Masters or Doctorate degree are a bonus, but this is rarely a requirement during recruitment. Employees are however required to be registered with a professional body.

From an engineering/consultancy perspective, graduates with different levels of qualifications are employed. Overall, a lack of practical experience with regards to the implementation of the theoretical knowledge (e.g. interpretation of data and decision making) and basic skills (e.g. writing and communication) remains a significant concern for graduates entering the engineering/consultancy sector. It was also outlined that certain emerging skill sets [e.g. synergy between wastewater treatment and energy generation (biogas to electricity), implementation and use of energy efficient systems, renewable energy, and linking processes to the circular economy/financial aspects] are lacking and required within the sector as the majority of the available knowledge is related to old and established subject fields (e.g. conventional wastewater treatment). Compounding this problem is the deterioration of available governmental infrastructure/erosion of technical capabilities, which sometimes prevents the implementation of certain innovative water-related technologies/intervention strategies that are developed in the engineering/consultancy sector. A “skills audit”/skills level assessment was subsequently identified as a way in which academic institutions can determine whether students are adequately equipped for the job market, while young graduates should also be encouraged to gain practical experience in the water sector (e.g. job shadowing) to identify whether they are on the correct career path.

Similar to the engineering/consultancy sector, the industrial sector employs graduates with different levels of qualifications. Skills gaps will differ from company to company within the industrial sector as there is such a broad scope of water-related needs and applications. Existing skills gaps are mostly related to specialist fields (generalist skills are not necessarily lacking) and therefore the organisations tend to recruit individuals with the required skills through bursaries. Additionally, the organisations tend to have a good relationship with tertiary academic institutions to run specific research projects related to the organisations. The outsourcing of specific research questions/topics to universities is generally conducted if a problem is not very urgent or sensitive, which helps the organisation to keep up to date with the water sector and then also helps to solve any problems the organisation may be facing in the future. In contrast, if a problem within the organisation is very urgent or sensitive, consultants are used to address the problem. However, this is also used as an opportunity to contribute to knowledge transfer into the company. A crucial skills gap that was however identified, involves the need for organisations to be very knowledgeable on relevant legislation related to the industry and sector (e.g. environmental legislation that needs to be taken into consideration with certain projects, legislation pertaining to water use and quality). It was thus recommended that graduate and postgraduate students be exposed to these aspects during their education.

In municipalities, graduates with national certificates, diplomas, advanced certificates and B-degrees are employed, while Honours, Masters and PhD graduates are less frequently employed. However, the required education level is dependent on the position. Overall, practical experience was outlined as the major skills gap for new employees, while the interpretation of data and report writing/communication was also identified as a lacking skill. The participants also highlighted that while the “higher level” positions within municipalities are important, the importance of the “lower level” positons (e.g. artisans/plumbers/electricians) for the service delivery of municipalities also need to be recognised and efforts need to be made to ensure that these employees are adequately skilled. It was suggested by the participants that compulsory in-service training/internships should be completed by engineers/scientists to gain more practical experience during their studies that will better prepare graduates for a career in the water sector.
Similarly, provincial and national government employ graduates with B-degrees, Honours (preferred over bachelor degree candidates) and Masters degrees, while PhD graduates are rarely employed as these graduates are regarded as specialists and there are limited specialists’ occupations available within government organisations. Specifically, within government organisations various graduates are hired, ranging from engineers to scientists. Additionally, registering with a professional body is a

requirement. Furthermore, soft skills such as telephone and email etiquette, conflict management, respect for colleagues and general life skills have however emerged as a problem area and individuals that have these skills in addition to professional qualifications is in high demand.

In the water boards or utilities, individuals with various graduate or postgraduate qualifications are employed. While Masters and PhD qualifications are not a requirement for most positions, employees are encouraged to promote themselves through postgraduate training programs. A lack of practical experience was identified as one of the major skills gaps within the organisations; however, it was acknowledged that a degree is seen as a base for further learning and that graduates need time to reconcile theoretical knowledge with practical application in the job market. Internship years are thus crucial, as the participants indicated that based on their experience, candidates who completed an internship year greatly improved their ability to link theoretical knowledge with practical application and comprehended concepts better. However, the lack of general skills (e.g. communication, report writing, working with general computer programs) in graduates are concerning (postgraduate employees are generally better skilled at writing technical reports and using logic to incorporate information for the completion of tasks), as well as the inability of employees to multi-task when entering the job market. Additionally, it was stressed that organisations need to ensure that candidates meet the requirements for the available positions at the entry level as there cannot be an overreliance on on-the-job training – "*ensure the requisite skills are there and then focus on up-skilling employees*". For example, as individuals do not necessarily have the requisite qualifications at the entry level, they may qualify for promotion based on experience, however, as their formal qualifications are still lacking, they are unable to be promoted to more senior positions where multiple additional skills may be required. Lastly, it was outlined that environmental/water/wastewater modules need to be included as part of the main component of available university courses (e.g. environmental engineering – theory and practical implementation).

Most notably, almost all participating sectors indicated that prospective graduates should familiarise themselves with the occupations on offer in the water sector and the specific requirements stipulated for occupations of interest for graduates. Furthermore, graduates are advised to join societies/clubs/institutes and to educate themselves regarding opportunities within the water sector. Job shadowing and volunteering at institutions where graduates would like to be employed has also been highlighted as an important tool which could aid in better preparing graduates for the workforce. In turn, a need for graduate intern programmes, job shadowing programmes and mentorship programmes has been stressed as these programmes aid in preparing graduates for specific occupations within the water sector.

4.3.3 Addressing skills gaps in the water sector

To address the skills gaps within the water sector, various learning interventions are employed by organisations. Overall, short courses, mentorship programs and on-the-job training have primarily been identified as the key drivers.

In the agricultural sector, depending on the organisation, various learning interventions may be applied. For example, it was noted by the participants that bursaries may be provided to employees to upskill themselves, while on-the-job training is primarily used to address the lack of practical experience within organisations. While the participants recognised the benefit of short courses, it was stressed that the available short courses do not necessarily focus on the current gaps within the sector, which were primarily identified as water legislation related, and as such, need to be re-evaluated.

CMAs allow employees to attend short courses to upskill themselves and to train employees in new techniques. However, the responsibility lies with the employees to identify short courses that they would like to attend and skills they may require to improve their job performance. It has been noted that all training and short courses that employees would like to attend, needs to be recorded in their performance reviews/personal development plans in order for the organisations to approve their attendance of these learning interventions.

From an engineering/consultancy perspective in the private sector, young graduates are often provided with a personalised career development plan and assigned a mentor to ensure that skills gaps are addressed. Additionally, technical communities (i.e. international experts to assist with problem solving), webinars and short courses are some of the commonly employed learning interventions to reskill and/or upskill current employees. Budgetary and/or accessibility issues and available time, were highlighted as barriers that are sometimes experienced during the implementation of learning interventions. Additionally, as there is no direct monetary gain, commitment issues with regards to the completion of learning interventions by employees has also been observed. Three main points were subsequently highlighted by the participants to address the lack of specific skills on a provincial and/or national level: (1) implementation of continuous professional training, (2) funding a national performance-based mentorship program that can run over a number of years – select professional mentors based on merit (e.g. potential to use retired engineers in this role as they have a wealth of knowledge) – and using mentorship reports to inform professional certification (ensure/inspire trainees to make the best of their training/mentorship opportunities) and (3) embrace the new generation of students' unique skill set – using technology, data/IT, digital skills – at the university level (undergraduate and postgraduate) to better prepare students and enable them to use these skills to enhance the water sector.

Organisations within the industrial sector employ various learning interventions to upskill or re-skill employees. For example, at certain organisations employees receive personalised development plans which are used to identify short courses or training interventions that the employees should complete, while it is also possible for employees to complete further formal qualifications (e.g. bursaries available for postgraduate qualifications at certain organisations). Additionally, the use of mentorship programs is widespread in the sector, whether it be for employees entering the sector or new employees transferring from another organisation. The mentorship programs aim to ensure exposure to the different aspects of the organisation and a smooth transition into new positions. Overall, on-the-job training has been shown to be more successful and produces more prominent results (i.e. more effective/faster outcome) in comparison to the use of strictly theoretical courses and it was recommended that a mix of interventions strategies be employed. Budgetary constraints were subsequently identified as the major barrier for training interventions (targeted first during financial constraints and must therefore be delayed). However, internal on-the-job training may be prioritised under these circumstances as compared to the use of external interventions. It was outlined that most of the water-related short courses that are currently available focus on potable water or wastewater treatment, which may not be directly applicable to organisations within the industrial sector; however the information from these courses nevertheless provides a good foundation for employees to build their knowledge and try and apply aspects of it within industry. Lastly, collaborations between organisations and municipalities was identified as a way in which skills gaps in the water sector can be addressed; however, there is a need to address existing infrastructural gaps within the public sector first. There is also a need to expose graduates to the broad field of water-related occupations so that they garner a better understanding of how water and water-related legislation fit in the water sector. It was also noted that the quality of research produced by certain tertiary institutions, as well as the quality of work being presented at national conferences, have decreased or stagnated in recent years. It was thus highlighted that priority should be given to the development of appropriate new subject matter

based on the identified skills gaps within the water sector, while the water sector also needs to evaluate how research influences water-related policies.

In the mining sector, consultants are often contracted to attend to water-related needs within mines. Specific employees are then often paired with consultants in order to facilitate knowledge transfer and this thus serves as a tool to upskill employees within mines. However, there is no formal training or short courses offered within the mining sector to upskill or reskill employees with water-related skills. It was thus recommended that knowledge within mines as well as the indigenous knowledge of the areas within which mines operate should be recorded. The knowledge could then be translated into short course material and formalised to offer employees within the mining sector learning opportunities.

Learning interventions in the form of short courses are mostly applied within municipalities to upskill/re-skill employees. Specifically, it was outlined that general workers at water works/wastewater treatment plants may be employed at an NQF level 1 classification and then upskilled to NQF level 4 through the completion of short course programs presented by LGSETA, with the participants also outlining that some municipalities have enquired with the short course service providers regarding the upskilling of employees to NQF level 5 and 6, respectively; however, there was uncertainty as to where these types of courses (NQF level 5 and 6) are presented. Additionally, it was outlined that the prioritisation of available funds (through employee bursaries) for the application of learning interventions remains a dominant barrier in municipalities. The establishment of diverse government funded training programs that will ensure that employees in water-related occupations in municipalities are adequately equipped with the required skills to ensure good service delivery was thus highlighted as a solution to this problem. The division of work, while certain employees are on leave to attend the short course training programs, was identified as an additional barrier during the implementation of learning interventions as employees need to work overtime to account for being shorthanded. Lastly, as there is no direct monetary gain, commitment issues with regards to the completion of learning interventions by employees has also been observed. Collaborations between the private sector and public sector were subsequently highlighted as the primary way in which the skills gaps in municipalities can be addressed on a provincial or national level, with the participants highlighting that there may be mutual benefits if the private sector contributes to the improvement of the public sector (e.g. invest in the public sector to ensure good quality water that industries within the private sector may be reliant on).

In provincial and national government, reskilling and upskilling of employees is limited as a result of budget constraints. Additionally, the number of people allowed to attend training sessions/courses/conferences is often limited. However, there are opportunities for employees to attend courses and conferences, as long as this is indicated on their personal development plans in advance. This allows the organisation to approve attendance of employees of these courses and conferences. It has also been noted that a skills gap analysis would aid the organisation in identifying where additional training of employees may be required, however this is not actively implemented. There is also often a lack of management with regards to the training of personnel and therefore training does not always occur. Furthermore, service providers are limited due to regulations (e.g. supply chain management regulations) imposed by the government, which limits training opportunities for staff.
Short courses, mentorship programs, internship programs and on-the-job training are all employed at the water boards or utilities, including formalised graduate training programs and in-service training for technicians. Development opportunities are also provided to general workers – e.g. in rural areas it is sometimes difficult to recruit employees from urban areas to go and work in remote rural areas, the focus has thus been to upskill employees already working in the rural areas for certain positions as they are more likely to stay. Recognition of prior learning has also been applied in the artisan space whereby artisan assistants with 4 to 5 years of experience are sent for a skills assessment at a recognised training centre. Following the identification of skills gaps, learning interventions are applied to

specifically address the identified gaps, where after the artisan assistant can then be sent for a trade test to become a fully-fledged artisan (artisan aid development program). With regards to the use of short courses as learning interventions, it was highlighted that in order for a short course to be effective, it needs to be related to job function and complement graduate training (improve report writing and presentation skills).

Financial constraints were most notably identified as the barrier preventing the implementation of learning interventions for water boards and utilities, as the financial performance of the organisation may prevent resources from being available to complete learning interventions or other factors may be prioritised over the implementation of learning interventions (e.g. health and safety issues may be prioritised over the implementation of learning interventions when budgets are allocated). Additionally, the demands of unions (e.g. type/focus of the learning intervention, how the learning interventions are conducted) were also highlighted as a significant barrier. The water boards or utilities therefore need to focus on balancing learning interventions based on what the union demands/wants versus the best interest for the organisation (needs to be in the best interest of the organisation to make the investment worthwhile). The possibility of immersing employees of state-owned enterprises/entities in the private sector for short periods to gain more experience in dealing with pressure and working at a high efficiency was identified as way in which skills gaps may be addressed on a national or provincial level. Additionally, discretionary grants need to be made available for the upskilling/reskilling of employees/implementation of personal development plans, based on the needs of specific organisations and not necessarily the water sector as a whole. Lastly, the training that is offered needs to lead to some sort of tangible qualification.

A key factor noted across all participating organisations is the need for collaborations and knowledge sharing between various organisations (private and public sector). Many participants stressed that if collaborations were fostered between different organisations and knowledge is more easily shared between different organisations, it will greatly improve the current functioning of various organisations and would reduce delays experienced in certain processes. Knowledge sharing and collaborations could also be used to upskill and reskill employees.

Furthermore, it has been noted that certain organisations are willing to partner with HEI to inform prospective graduates of the opportunities available in the water sector. It has also been suggested that organisations in the water sector and HEI could partner to develop courses that are tailored to specific occupations in the water sector and to formalise certain available occupations or positions in the water sector. Moreover, compulsory professional development courses should be reinstituted which offers postgraduates specialised training in a specific occupation.

Based on the feedback received during the completion of the focus groups, it was concluded that while the quality of young graduates entering the job market has improved in recent years, the lack of practical experience amongst water-related occupations is still a significant concern. The specific skills deficiencies are then mostly organisation/sector dependent, with certain sectors using external specialists (e.g. consultants) or employing graduates/postgraduates with specific expertise/specialist training, to address these specific skills gaps. However, the over-reliance of using external specialist was also identified as a challenge that needs to be addressed within certain organisations/sectors. Within provincial and national government, it was outlined that there is not necessarily a lack of specific skills, but rather a lack of internal structures to capitalise on the available talent/skills entering governmental organisations, as individuals are not always appointed in positions where their skills would be most beneficial. The number of vacancies and positions that experience a high staff turnover rate were also organisation/sector dependent. Overall, vacancies in senior level positions were the most difficult to fill due to the stringent and specific job requirements (job experience being essential).

Organisations within the private sector were reported to be less likely challenged with regards to vacancies or positions that experience a high staff turnover rate due to competition from the external market/public sector. Additionally, while certain organisations within a sector may experience higher staff turnover rates, the knowledge is not necessarily lost to the sector, as individuals may move to a different organisation within the same field.

Overall, most of the organisations in the water sector employ Bachelors, Honours and Masters graduates, with Doctoral candidates less frequently employed as PhD graduates are regarded as specialists that tend to go into research specific fields in the academic, industrial, and RDI sectors, respectively. Additionally, registration with a professional body was outlined as a key requirement for organisations within the various sectors.

A consensus amongst the participants was that enough PhD graduates are available for the job market; however, the available positions within organisations for PhD graduates are limited. Additionally, there is a general sense that (1) PhD graduates may be too specialised or considered “over-qualified” for certain positions, (2) PhD graduates are considered more expensive to employ (or expect higher salaries due to their academic qualifications) as compared to Masters or Honours graduates that may have more work experience, (3) not all PhD graduates are willing to enter an organisation at lower level positions, or if they apply for these positions they have to compete with a significant number of Bachelors, Honours and Masters graduates that organisations will preferentially employ, (4) PhD graduates are not always aware of the positions that are available to them (PhD graduates are often trapped within an academic bubble and not necessarily aware of the opportunities in the private sector), (5) following approximately 9 years of studying, most PhD graduates do not necessarily have the job/work experience that is required by certain organisations.

Similarly, a PhD tracer study of water-related PhDs awarded between 2013 and 2017 in South Africa by Pouris and Thopil (2020) indicated that all the PhD graduates (107 traceable profiles) were employed, however, 57% of the PhD graduates were employed within academics (universities), with 23% of these graduates filling postdoctoral fellowship positions. In contrast only 16% of the PhD graduates were employed in the private sector, 12% in semi-government, 15% in government and 4% in non-government organisations (for 8% of the PhD graduates no information regarding sector of employment could be detected).

Thus, while the National Development Plan of 2030 aims to significantly increase the number of PhD graduates in South Africa and aim to make this qualification more desirable for prospective graduates, a significant gap in this plan is the employment of these graduates (increasing the absorption of these graduates into the private sector workforce and more permanent positions in academia). Furthermore, funding opportunities for PhD students are decreasing.

Lastly, the focus group participants indicated that various learning interventions are employed by organisations to address the skills gaps within the water sector. Overall, on-the-job training, short courses and mentorship programs were primarily identified as the key drivers. However, each type of learning intervention experiences its own barriers, with budgetary constraints and a lack of experienced mentors most notably highlighted. Additionally, it was stressed that the available short courses do not necessarily focus on the current gaps within the various sectors. Priority should thus be given to the development of appropriate new subject matter based on the identified skills gaps within the water sector and organisations in the water sector and HEI should partner to develop courses that are tailored to specific occupations in the water sector and to formalise certain available occupations or positions in the water sector. Collaborations between the private sector and public sector were also highlighted as

a means to address skills gaps on a provincial or national level, with the participants highlighting that there may be mutual benefits if the private sector contributes to the improvement of the public sector.

4.4 FUTURE SKILLS

Various factors, including climate change, pollution, and technological advancements amongst others, have influenced the water sector with regards to water provision, quality and usage in recent years. Semi-structured interviews were thus conducted with key stakeholders in order to determine which factors/themes will most notably drive change in the water sector and thus need to be addressed to better prepare the water sector for future opportunities, challenges and risks it may face. Five individuals participated in the semi-structured interviews (n = 5). A participation rate of 41.6% was obtained from the total invited participants (n = 12).

The identified factors included:

- Resilience *(flexibility and critical thinking)*
- Data and analytics *(digital literacy, internet)*
- Leadership *(strategic planning, management, learning, communication, culture, etc.)*
- The customer *(service, culture and experience)*
- Technical skills *(network operations, engineering, general operation, risk management, knowledge management)*
- Delivery models *(contracting, outsourcing, insourcing)*
- Entrepreneurship *(innovation)*
- Collaborations *(partnerships with other sectors)*

Overall, the response from the interviewees indicated that the South African water sector is robust with regards to available skills and has a good base to work from; however, several critical elements/factors need to be addressed in order for the water sector to be better prepared for future demands. Importantly, it may not only be a single individual factor that drives change within the water sector, but it will most probably be a combination of these factors and an interplay between these factors, that will change the water sector as it is currently known. Although all the outlined factors/themes were thus identified as "relevant", it was highlighted by the interviewees that certain factors need to be addressed first to ensure the success of the others.

Most notably, **leadership** was identified as a critical factor that needs to be addressed to ensure the functionality and capability of the water sector. Specifically, within the **leadership** theme, it was outlined that (1) improved **strategic planning** and **management** will allow for the translation of available knowledge into service delivery by ensuring streamlined and effective procedures, (2) individuals that are willing to take risks and to challenge the status quo in the water sector in terms of existing frameworks and implemented technologies are required, and (3) there is a need for strong **leadership** that understands the gap between what the water sector is committed to do and what the water sector is able to do, and that will actively work to try and bridge these gaps (using available resources, working with target communities and through sound decision making). – *"While **data and analytics** are the current buzz words for the future and important to consider, we first need leadership in order for us to get the benefit. If the leadership and management is lacking, data and analytics are not going to help – Garbage in Garbage out".*

Entrepreneurship/Innovation was then also highlighted as a critical factor/theme that may drive change in the water sector as developing countries, like South Africa, should strive towards a

knowledge-based economy rather than a resource-based economy. It was noted by the interviewees, that while South Africa has various sectors of excellence that produce world class research driven outputs, the amount of knowledge being translated to the marketplace, in comparison to overseas counterparts, remains a significant concern (ensuring access to markets and uptake of solutions). Specifically, the development of technologies in South Africa, followed by the commercialisation of the technology/product overseas, only for the technology/product to be imported back to South Africa, is concerning. A lack of funding and entrepreneurship skills within the sector were then identified as the major contributing factors to this problem (not translating research outputs to technologies/products for the marketplace). Funding limitations hamper research efforts and deter talented professionals from pursuing careers within the water sector, which in the long term, will have a detrimental effect on the pool of professionals with skills to develop and innovate within the water sector. Investing in entrepreneurs to develop innovative solutions thus need to be prioritised by the government and other funding organisations. Additionally, while enterprise development in academia may be improved by updating education programs or by bringing in entrepreneurs from other sectors to improve the skills in the water sector, it was stressed that the "metrics" which are commonly used to assess the efficiency/success of innovation agencies and funding organisations need to be realigned from "number of innovations funded and percentage of budget allocated" to the more pragmatic "quality/impact of the innovations and number of innovations making it to the marketplace". The accurate assessment of the return on investments for government funded programs (e.g. technology development, human capital development), will allow for the determination of whether available funds are being spent on the right things – "*We need to determine the trade-off for money used for R&D (research and development) and its success, compared to the use of the money for basic human needs (homes, schools, healthcare)*".

From an academic and research perspective a major driver in the water sector is hypothesised to be related to interesting and exciting **innovations**. This will inspire and motivate professionals such as engineers and scientists to pursue careers within the water sector. Additionally, as water needs in urban cities change (water scarcity and the need for more advanced water reclamation systems and water purification plants), there will be a need for new technologies to meet this demand. It is thus of utmost importance to inspire and excite professionals to enter the water sector where their skills may become more sought after in the future. Linked to **innovations** within the water sector and inspiring professionals to pursue occupations within this sector, is the need to change how research is conducted for the development of new interventions. For example, opportunities will need to be created where individuals are allowed to take risks and to try new technologies/innovations and to test new ideas. Building and creating sites (so called "urban living laboratories") where engineers and scientists can build and test systems to address needs within the water sector, is thus required. This will enable professionals to bridge the gap between research and implementing innovations in the field and may also improve the quality of interventions developed in South Africa. A middle ground will thus need to be reached where both a market-based approach (what is needed) and an academic-based approach (what is interesting and innovative) are combined when developing and funding new technologies.

Moreover, while conventional linear thinking is required when identifying and trying to solve problems within the water sector, the diversity of challenges associated with each type of consumer also needs to be taken into consideration. In terms of the future skills demand and changes in the types of occupations required in the water sector, there is and will be a need to move to a **transdisciplinary approach**. The water sector is often dominated by professionals such as engineers (which is crucial for infrastructure design, etc.), while health scientists and social scientists are less frequently consulted on processes within the water sector. Similarly, scientists such as biologists or environmental scientists are often used in water quality laboratories, but there is a need to start including these scientists in for example, the processes where water treatment systems are designed. Sharing knowledge across

various fields and disciplines will aid in designing innovative technologies to address the demands within the water sector that will be to the benefit of South Africa.

Similar to the need for transdisciplinary approaches, **collaboration** between the public and private sector was also identified as crucial for the future water sector demands, as the skills gaps within one sector may be addressed by the available skills/expertise in another sector. The interviewees also indicated that the gap in collaboration between the public and private sector may be bridged by highlighting the mutual benefits for each partner which may be obtained as a result of the collaboration. Increased collaborations may then also reduce the potential unnecessary duplication of knowledge, as multiple organisations often work on the same type of programs/research topics. By determining what knowledge (information/platforms/programs/initiatives/networks) is currently available and how to best work together with this existing information, collaborating organisations will be able to help one another to continuously build on the existing/available knowledge.

The customer, more specifically, the customers viewpoint was also identified as a critical factor/theme that may drive change in the water sector. As legislation mandates the provision of water and sanitation services to all South Africans as a constitutional right, there is a misconception that all water and sanitation services should be free of charge. It was outlined in the interviews that this mind-set needs to be translated to one whereby the need for minimum basic service delivery is acknowledged, but it is also acknowledged that everyone needs to play their part and pay for the services provided. However, this mind-set of the customer not willing to pay for improved water and sanitation services should not be attributed to a sense of entitlement (people not willing to pay as they want it for free), rather it may be attributed to the "product" (water and sanitation) not being packaged properly for the target communities. How the customers' narrative towards water and sanitation services/products can be changed to ensure a sense of ownership, was subsequently identified as a crucial factor to drive change in the water sector.

"The common national geographic image/narrative of water and sanitation in Africa – poor Africans crowding around a tap looking at the water like the water is going to save them – that kind of image filters down into the way services are being provided to these communities. The design of the technologies, the way these services are being provided is done from this viewpoint. The technologies or interventions are thus not seen as aspirational. People don't see value in it and if you don't see value in something, then people won't be willing to pay for something."

Sanitation services in indigent communities was primarily used as an example in one of the interviews, whereby pit latrine or communal toilets are provided by local governments to the communities. However, because there is no sense of ownership towards these technologies by the communities, these systems are simply abandoned at the first sign of trouble and subsequently it is the responsibility of the local government to use minimal available resources to maintain these systems. The disjoint between services for the poor versus services for the rich and the failure of water and sanitation intervention strategies (specifically in indigent communities) was subsequently related back to leadership and innovation – how are the products/services marketed, how are the roll-outs planned, what was the level of communication between the target community and the "developers", how are the communities approached to determine whether there is interest in the product/service and whether people are willing to pay for the product/service.

Due to procurement issues, red tape and excessive paper work, it is sometimes difficult to implement new solutions in the water sector. Improved **delivery models** are thus required to ensure a more efficient and faster uptake of solutions that are needed to make a more efficient water sector. Additionally, **contracting** and **outsourcing** have the potential to allow for knowledge transfer under

certain circumstances, thereby increasing skills development in the water sector. Lastly, **data and analytics** will play a crucial role in the future water sector. There is a need to obtain decent data to monitor processes within the water sector and to obtain data within a reasonable time frame. The analyses and interpretation of the acquired data will then also allow for the identification of future trends and needs/shortcomings within the water sector.

Additionally, the **re-evaluation and adaptation of our current point-of-view** was identified as an additional crucial factor/theme for future change in the water sector. Specifically, it was outlined that the diversity across South Africa and the complexity associated with specific problems needs to be acknowledged. As situations are different from region to region (and even different within the same region), a single approach will not work everywhere and as such, individual solutions to specific situations are required – *"What we think is going to work and what has been shown internationally to work, might not work here in South Africa"*.

Lastly, interviewees were asked how institutions/organisation can prepare for the outlined changes in future skills demand in the water sector. One of the themes that emerged during the discussion is that "islands" exist within the water RDI structures, where you find that multiple institutions are running the same type of program/conducting the same type of research, however, there is no collaboration between these organisations, which results in a wastage of resources/funds and results in projects that don't deliver the desirable results. It was subsequently highlighted that synergy needs to be established between institutions so that the water sector is able to reach its goals faster. The need for systems that will enable the management of collaborations between institutions was stressed; however, these management systems should not be mistaken for "Centralisation" (as this may increase bureaucracy, slow down processes, may increase inefficiency, etc.), rather organisations should establish distribution bodies that work with their collaborators to reduce redundancy (e.g. generation of same background knowledge by multiple projects – i.e. progress is not made).

The need for innovative training programs to equip individuals in industry with practical experience and then also equip individuals with new skills (upskill employees) to deal with future challenges was outlined. This may then be achieved by translating and developing the knowledge obtained from collaborative research ventures into sophisticated training courses by academic/research institutions to better prepare current and future employees for a career in the water sector – *"Continuous capacity development is essential to meet future skills demand"*. For example, the effects of climate change on South Africa, which is already a water-stressed country, and increased migration of citizens to main city centres will become more pronounced in the coming years. We therefore need to invest in appropriate technologies and equip our problem solving toolkit for the future challenges posed by climate change and population growth/migration. It was also stressed that training courses should be practical and should focus on developing sustainable systems within the water sector (for example, not just developing a wastewater treatment plant, but developing a system that treats wastewater and reclaims water). Additionally, the need for in-service training to form part of degree programs is a critical aspect that needs to be implemented in South Africa to better prepare the future skills workforce.

From an international perspective, it was noted that the outlined factors/themes may change water sectors to varying degrees. For example, the water sector is shifting to be more **resilient/flexible** and apply critical thinking to identify and adequately respond to potential problems before they arise (as compared to responding to needs as they arise), with the implementation of water safety plans/risk abatement plans increasing and communication structures improving (incorporation of phone trees instead of a linear chain of communication). **Data and analytics** was subsequently identified as the most rapidly changing factor, primarily due to the COVID-19 pandemic expediting the uptake of digital technologies (e.g. machine learning, edge computing and remote management) by water sectors

worldwide. Additionally, it was outlined that increased access to mobile technology (use of apps, e.g. how to operate a particular large valve/how to open close valves to prevent water hammer, etc.) may skew the workplace towards younger people that are more intuitively technologically savvy and promote the uptake of new skills via online platforms (i.e. increase electronic learning). However, the increased online learning should not result in decreased practical training (**technical skills**) as a component of teaching courses – "*institutions will need to pick up the practical aspect of training and work a little bit harder on things like on the job training and apprenticeships*". **Customer** experience and service delivery were also highlighted as critical factors that will drive change in the water sector, specifically in developing countries, where the use of online payment methods (e.g. via an app) have increased revenue collection and capital expenditure projects have focused on improving service delivery for customers in rural/remote areas (e.g. piped water supply being more economically feasible than continuing to transport water via tankers over the long-term). With regards to **innovation**, it was highlighted that one of the drivers of change needs to be the acceptance of scientific rigor and understanding that there are many steps to go through to get from a research and development phase to commercialisation and implementation of the developed product – "*developers tend to rush to the market too quickly with an idea that is touted as pre-commercial when it's not*". Lastly, **government policy** will drive change in the water sector, as organisations will need to adapt and adhere to new regulations (e.g. sustainability, incorporating environmental protection and public health protection into core business plans).

The COVID-19 pandemic has significantly influenced all aspects of general life worldwide, with various sectors needing to adapt to new situations. Based on the past years' experience, interviewees were asked to hypothesise how they foresee the COVID-19 pandemic will influence the water sector and how the water sector can be better prepared for similar disruptions in the future.

"The pandemic has been a tragedy with regards to people losing their lives, people struggling with their health and the economy has been hit hard causing more problems; however, the greatest loss would be if we do not learn from this situation and merely go back to the way we were doing things before and not incorporate the lessons that we have learnt – COVID-19 has allowed us to see our world from a different perspective."

As water continues to be a critical part of preventative measures for SARS-CoV-2, the COVID-19 pandemic has primarily highlighted the need for water access and is forcing water sectors across the world to reassess infrastructure needs to ensure a reliable supply of water to all citizens. The ability of wastewater treatment plants to allow for wastewater-based epidemiology within a community has also been brought to the forefront of scientific focus and is a technique that may be applied in the routine analysis of community health in the future. Shifting from conventional water monitoring benchmarks to the newly identified benchmarks and techniques (e.g. wastewater-based epidemiology, quantitative microbial risk assessment, microbial source tracking) is valuable and will aid the water sector to better respond to future challenges. The COVID-19 pandemic has thus highlighted that the water sector cannot focus on short-term solutions in response to crisis such as a pandemic. There is a need to learn from events in the past (such as drought and "Day Zero") and to implement what has been learnt and the solutions that have been put forward, in the long run. The focus needs to shift from a reactive or response system, to a sector that is prepared for any crisis. It is imperative that the water sector learns and absorbs the information acquired from past experiences and implement it.
Another major impact that was subsequently identified, is the future availability of funds for research and academic institutions and skills development programs, due to the impact the COVID-19 pandemic has had on the economy and government revenue. Organisations will thus need to devise innovative ways in which to minimise the impact from this financial short-fall.

Additionally, professionals have been forced to explore new tools and communication platforms in order to communicate with colleagues and collaborators and this in itself has contributed greatly to the skills set and professional development of many South Africans. While certain conferences, workshops and networking opportunities have needed to be cancelled or postponed, others have moved to online platforms. This in turn has increased access to these opportunities for individuals that may not have been able to afford (cost-prohibitive) or to travel (geographically restrictive) to these events under normal circumstances. The COVID-19 pandemic has thus also allowed for the establishment of more inclusive events with improved access for individuals. The COVID-19 pandemic has also changed the way learning institutions think about teaching and learning as many universities have adopted hybrid learning systems to teach students. In terms of the academic arena and education accessibility, this may offer a wider audience of students access to higher education and potentially decrease tuition costs if they can attend classes online in future.

Additionally, it was outlined that certain organisations have seen a spike in productivity, as employees are losing less time commuting to work and may be exposed to less distractions working from home, while the use of online training initiatives (skills development programs) have also increased – "*Skills training can be employed through online virtual training using virtual reality/3D modelling programs*". It was also outlined by the interviewees that the various online platforms be used to create interactive content and promote the dissemination of information (data is usually hidden in online repositories in large documents, making the information difficult to access for policy makers/general public) related to the water sector.

CHAPTER 5: LIMITATIONS OF CURRENT STUDY

The main limitation in the current study was the low response rate of the survey (9.44%). South Africa was in Lockdown level 1 during the time the survey was active (21 October to 9 November 2020). In the United Kingdom a survey was conducted by the Chartered Institution of Water & Environmental Management (CIWEM) to study the challenges the UK water sector faces due to COVID-19 and to identify best practice and learning opportunities (Cotterill et al., 2020). The survey consisting of 30 questions was emailed to 8000 CIWEM members from 18 May to 5 June 2020. Respondents included in the UK study, as in the current study, included water and wastewater service providers, consultants, contractors, regulators, local authorities, central government and manufacturers. The response rate was 6.3%, similar to the response rate of the current study. This indicates the difficult circumstances during which both studies were undertaken. Supplementary data was therefore obtained through a series of semi-structured focus group interviews with key organisations within the water sector as well as future skills interviews with key role players.

CHAPTER 6: CONCLUSIONS

The questionnaire, distributed to 445 stakeholders, had a response rate of 9.44%. Although the response rate was low, respondents of key organisations from the agricultural sector; CMAs; consultancy and engineering; RDI sector; industrial sector; mining; municipalities; national or provincial government; and water boards participated. However, no respondents from the manufacturing sector completed the questionnaire.

The questionnaire results indicated that the top ten skills in demand in the water sector are: “using large scale datasets (Big data)”; “information management”; “GIS and remote sensing”; “time management”; “understand the internal and external environment”; “training”; “risk management”; “participation in research and development”; “sampling and data collection”; and “supervision of staff”. Major skills gaps identified during the focus group interviews were, amongst others, related to skills obtained through practical/work experience and the lack of organisations’ capacity to mentor, train, teach and develop young professionals to bridge this gap was highlighted.

In the water-related RDI environment the questionnaire results indicate that the top ten skills in demand are: “risk management”; “visioning”; “information management”; “new business development”; “social astuteness”; “understand the internal and external regulatory environment”; “dissemination and exploitation of research outcomes”; “networking ability”; “understand the business environment in which the company operates”. The following skills are all at position ten “commercial awareness”; “emotional intelligence”; “integration”; “leadership skills”; and “using large scale datasets”. Major skills gaps identified during the focus group interviews for the water-related RDI environment were related to the use of large scale datasets and the ability to take science to the society. The lack of social sciences and socio-ecological-systems within the water-related RDI environment was also noted.

Of the 45 OFO occupations included in the questionnaire, the vacant option was selected for all the occupations except for Local Authority Manager (Water Services Manager). Similarly, the vacant option was selected for all the occupations in the water-related RDI environment. Reasons for the vacancies for the occupations in the water sector were recorded as: “candidates not registered with professional body”; “economic climate”; “lack of experience”; “lack of qualifications”; “poor remuneration”; “slow recruitment process”; and “unsuitable job location”. Only nine occupations had “new or emerging job” listed as one of the reasons for a vacancy while no occupations had “unsuitable working hours” listed as a reason. In contrast, in the water-related RDI environment respondents of the questionnaire were more selective, with between one to three reasons listed as reasons for vacancies for each respective occupation. None of the respondents selected the reasons: “candidates are not registered with professional body”; “unsuitable job location” and “unsuitable working hours” as reasons for vacancies for any of the occupations in the water-related RDI environment.

During the focus group interviews, current vacancies in the respective organisations of employment were recorded for engineers, hydrologists, geohydrologists and project managers. Reasons for the respective vacancies were noted by the interviewees to include, amongst others, relocation to cities, better career opportunities and remuneration, lack of relevant work experience, lack of relevant qualifications, lack of registration with a professional body, and late submissions of applicants.
Of the 45 OFO occupations included in the questionnaire, the high staff turnover rate option was selected for all the occupations except for Local Authority Manager (Water Services Manager). Similarly, the high staff turnover rate option was selected for all the occupations in the water-related RDI environment. Results from the questionnaire indicate that the high staff turnover rate for the

occupations within the water sector, as reported by the respondents of the respective organisations, are: “contract closure”; “dismissals”; “economic climate”; “resignations”; and “retirement”. In contrast, the reasons for high staff turnover rates for occupations within the water-related RDI environment, as reported by the respondents of the respective organisations and institutions, are: “contract closure”; “resignations”; and to a lesser extent the “economic climate”.

During the focus group interviews, high staff turnover rates were reported for municipalities and the provincial and national government mainly due to the private sector and the different types of municipalities (local, district and metropolitan municipalities) able to offer more competitive remuneration packages.

Results from the questionnaire indicate that all the listed learning interventions are applied to reskill and/or upskill all the occupations in the water sector and the occupations within the water-related RDI environment. The only exception was Technology Transfer Officer as none of the respondents selected the occupation as filled within their organisation of employment. Formal qualification, Professional registration and CPD, Short courses and Workplace learning (mentoring system) were selected as learning interventions for all the occupations included in the study.

During the focus group interviews short courses, training programmes, webinars, conferences, using outsourcing and contracting as a tool for knowledge transfer, and the use of personal career development plans were identified as learning interventions currently employed by the interviewees’ organisations of employment. Although the interviewees acknowledged the opportunity for employees to attend short courses to reskill and upskill themselves, barriers such as budget constraints, commitment issues due to no monetary gain for attending learning interventions, division of work while certain employees are on training, lack of management of training of personnel, and lack of government-approved service providers were reported. Professional registration was also noted as an important criterion for employment in certain sectors while the importance of workplace learning (mentoring system) was also reported.

It was observed that most of the organisations that form part of the water sector employ Bachelors, Honours and Masters graduates, with doctoral candidates less frequently employed as these professionals tend to go into research specific fields. A tracer study of water-related PhDs by Pouris and Thopil (2020) indicated that all the PhD holders (107 traceable profiles) were employed. It should however be noted that 57% of the surveyed PhD holders were employed within universities. Furthermore 23% of those employed within the university sector held post-doctoral positions. In contrast, only 16% of the sample size was employed in the private sector, 12% in semi-government, 15% in government, 4% in non-government organisations and for 8% no information regarding sector of employment could be detected. The WRC is currently conducting a cross-sectoral PhD study to, amongst other, trace the mobility and career paths of PhD holders, in all fields, in South Africa (WRC, 2020).

During compilation of the literature review for the future skills component of the current study, it was identified that factors such as data and analytics, leadership, the customer, delivery models, (contracting, outsourcing, insourcing), entrepreneurship (innovation), and collaborations (partnerships with other sectors) will drive and facilitate change in the future water sector and will influence the future skills required within the water sector. During the future skills semi-structured interviews it was highlighted that all of these factors play and will play an important role in the future water sector of South Africa. However, it was also stressed that additional factors may play a role in the South African context. Importantly, it was stressed that the water sector needs to create opportunities that will excite professionals to pursue a career in this sector in order to draw those specialised skills into the sector

and to retain those skills in the long run. This will require innovative thinkers and leaders that challenge the status quo within the water sector, to push the boundaries and to create opportunities for the future generation of professionals considering a career in the water sector. Additionally, it was stressed that the challenges faced (for example the drought and “day zero”) and mitigation strategies implemented (for example strict water restrictions and the promotion of the use of alternative water sources such as harvested rainwater) in the sector, needs to be used to build a sustainable water sector and that these strategies cannot merely serve as a “plaster” to temporarily address problems. The sector needs to adapt to the “new normal” and to implement more permanent solutions to the ever increasing challenges faced related to water in South Africa. This will also require innovators and leaders that can design these permanent solutions and ensure that they are adequately implemented. Furthermore, this will require a more transdisciplinary approach which will not only consider engineers but will also require the inputs from health care professionals, health scientists, social scientist, natural scientists, economists and many more occupations and professionals. Thus, a greater diversity of professionals and occupations within the water sector workforce and by extension a greater set of diverse skills will be required in the future water sector of South Africa.

As stated earlier the COVID-19 pandemic has impacted skills development negatively in the water sector due to the cancellation of certain training and networking opportunities. However, strategies applied by different organisations to continue with learning and skills development using online platforms (i.e. hybrid learning at HEIs and offering of online short courses, training programmes and conferences) during the pandemic could increase accessibility to individuals and should be further investigated in long term skills planning of the water sector.

Important trends noted in the report are the demand of professionals with skills in data and analytics, as well as leadership in the water sector. The questionnaire results indicated that “using large scale data sets (Big data)” was the skill with the highest number reported vacancies in the water sector questionnaire while it was in position ten in the water-related RDI questionnaire. Similar findings were observed for the focus group interviews with interviewees in the water-related RDI environment reporting that professionals able to handle, manage, store, and effectively interpret large data sets are in high demand. It was also noted during the engineering/consultancy and municipality interviews that the interpretation of data was also a skill to be found lacking amongst individuals. It is especially a matter of concern if it is taken into consideration the crucial role data and analytics will play, as observed during the future skills interviews, in the water sector to identify future trends and needs/shortcomings. The role of leadership as a critical factor to ensure the functionality and capability of the water sector was also noted in the future skills interviews. Therefore, the lack of leadership skills, as noted in the results of the water sector and water-related RDI questionnaires, should be addressed.

CHAPTER 7: RECOMMENDATIONS

The following recommendations are made to address skills gaps in the water sector, based on the quantitative and qualitative findings of the study.

- Numerous interviewees in various sectors have indicated a lack of skills which does not pertain to a qualification but rather the lack of practical and/or job experience. Based on the qualitative findings the following recommendations are made:
    - Students and young professionals should start to gain practical experience in the relevant organisations within the water sector early in their careers. Volunteer work, where feasible, and job shadowing, graduate intern- and mentorship programmes have been suggested in this study as possible means to achieve this. These findings were also highlighted during the NSTF (2016) during which suggestions were made to re-instate the past practice of offering mentorship and creating opportunities for graduates to attain practical experience in the workplace.
    - Once employed within organisations more capacity should be developed to mentor and train young professionals in order for them to gain work experience to one day be able to occupy more senior positions. On-the-job training/in-service experience and mentorship should be promoted and utilised to upskill employees. The collaborative project 'Vision for Water Capacity Building in South Africa' of IWETS also recommended the coordination of high-quality on-the-job training initiatives and life-long learning programmes as a learning intervention.
    - To equip the future skills workforce better, training courses and programmes should have a practical component while in-service training could form part of degree programmes, where feasible. During a national stakeholder workshop held in 2017 as part of the African Centres of Excellence (ACE) Water2 project the relevance of a shift of focus from training of testing of academic knowledge to training focused on the ability to perform the tasks required by an occupation was noted (ACEWATER2, 2018).
- To integrate the development of soft skills (e.g. telephone and email etiquette, conflict management, respect for colleagues, etc.) and leadership skills into training. The same recommendation has previously been by made the NSTF (2016).
- Short courses, training programmes and conferences have been identified by various sectors as an important learning intervention to upskill and reskill employees.
- To utilise contracting and outsourcing as tools for knowledge transfer, under certain circumstances, as this can increase skills development in the water sector.
- To foster and build collaboration between organisations and institutions within the water sector by improving communicating, promoting a culture of understanding and investigating the sharing of knowledge and resources. The need for increased synergy between the public and private sector as well as between organisations and institutions involved in water-related RDI activities were highlighted in this study.
- To foster and build collaboration between HEIs and organisations within the water sector. Memorandums of Intent (MOI) and Memorandums of Understanding (MOU) can be signed between HEIs and stakeholders, such as the DWS, to train students with specific skills. These individuals can then be adsorbed into the relevant government organisations where further training can take place. It can also provide the DWS with the opportunity to visit HEIs to inform and educate graduates and postgraduates on the role and work of the department. The NSTF (2016) has previously recommended career guidance for high school learners as an important

intervention to promote water sector qualifications and careers but findings from this study highlights that this intervention can also take place at tertiary educational level.

- Recommendations which are specifically applicable to the water-related RDI environment in both the private and public sector are the following:
    - To develop entrepreneurial skills within the water sector to assist with the translation of research outputs to technologies/products for the marketplace. The "metrics" or assessment criteria used to evaluate the efficiencies of innovation agencies and funding organisations as well as limitations in funding should also be addressed to motivate professionals to develop and innovate in the water sector.
    - The construction and creation of sites ("urban living laboratories") where R&D projects can be piloted could assist in building innovation capacities among professionals as well as the development of the necessary skills required for the implementation and maintenance of any new technology. This could also create the opportunity for engineers, biologists and health scientists, amongst others, to work together through a transdisciplinary approach which in turn will increase professional's multi-disciplinary skills. The need for transdisciplinary skills to solve problems in the water sector (NSTF, 2016) and for multi-disciplinary talent amongst PhD graduates (Pouris and Thopil, 2020; NSTF, 2016) has been previously documented.
- Although the COVID-19 pandemic has led to the cancellation of certain training and networking opportunities, there has been positive impacts and development of skills in the water sector. These lessons learnt should be taken into consideration in the long term skills planning of the water sector and are, amongst others, the following:
    - Online conferences, workshops and networking opportunities have created more inclusive events and have improved access to individuals that may not have had the opportunity to attend due to financial and travelling constraints. It has been reported by municipalities that travelling to service providers for training opportunities not only has financial implications but it is also problematic to find an individual to take over the responsibilities of the person(s) absent while on training. This of course has a bigger impact on small and rural municipalities (LGSETA, 2016). The opportunity of online training and networking events could be used to address this problem, but innovative solutions will be required to address the practical component of training courses (i.e. hybrid training courses) and the accessibility of data.
    - The hybrid learning systems HEIs had to adopt during the pandemic have the potential to increase accessibility to these institutions by future students.

For each recommendation made in the current study examples of existing South Africa and African skills development initiatives, programmes and networks are provided in Table 15. However, the list contains only a few selected examples and is therefore an area for future research.

Table 15: Corresponding the recommendations of the current study with examples of existing South Africa and African skills development initiatives, programmes and networks

Recommendation	South Africa/African skills development initiative, programme or network
To train and mentor graduates and young professionals	• The Young Water Professionals South Africa (YWP-ZA), a division of WISA and the International Water Association (IWA), assists students and young professionals by providing opportunities to network, collaborate and communicate as well provide career development opportunities through workshops, conferences and roadshows (YWP-ZA, 2020).
To mentor and train employees within organisations	• Individual municipalities have reported the use of internal mentoring and training of to prepare candidates for vacant positions or for positions where the current employee is nearing retirement. Internal mentoring and training is therefore an integral part of these municipalities succession planning (LGSETA, 2016).
To incorporate practical and work experience components into training courses and degrees	• The occupational qualifications developed by FETWater not only incorporates a knowledge component into the curriculum but also a practical component and a work experience component (FETWater, 2018).
Integrate the development of soft skills and leadership skills into training.	• Stellenbosch University offers the short course Water Governance for Water leaders with the objective "*to provide a foundational orientation to the concept of leadership and provide for contextual and conceptual issues of leadership within the paradigm of water governance*" (Volume 3).
To continue with the learning interventions: short courses, training programmes and conferences	• The short course mapping tool developed as part of the WRC RDI Roadmap Skill Mapping Study can provide information to organisations and institutions within the water sector with regard to the relevant water-related short courses available.
To use contracting and outsourcing as a tool for knowledge transfer	
To foster and build collaboration between organisations	• The Water Technology and Innovation Forum, recently launched by the WRC, DWS, COGTA and SALGA, aims to provide a collaborative platform for municipalities and their partners to address problems in the water and sanitation departments using innovation and technology. On the skills side, peer to peer learning and knowledge exchange on innovative solutions will be included in their projects and programmes (South African Government, 2020). • WaterNet is a regional network in Southern and Eastern Africa consisting of higher education, research and training institutions with the objective to build human capacity in Integrated Water Resource Management (Jonker et al., 2012).

To foster and build collaboration between HEIs and organisations	• Universities in Uganda (Kayaga, 2017) and Nigeria (Onime and Uhomoibhi, 2012), have indicated that collaboration between HEIs and organisations in water sector is an important building block to facilitate capacity building amongst professionals. Barriers against effective collaborations were identified as, amongst others, institutional and attitudinal obstacles (Kayaga, 2017).
To develop entrepreneurial skills within the water sector	• VIA Water, a Dutch programme, provides seed capital to innovators in seven African countries (Benin, Ghana, Kenya, Mali, Mozambique, Rwanda and South Sudan) as well as invests in building entrepreneurial and innovation skills (Nagel et al., 2018). It provides support through a virtual community as well as annual skills seminars and learning tours (Mvulirwenande and Wehn, 2020). • In South Africa, the Technology Transfer Agency (TIA) has Innovation Skills Programmes which provides skills development initiatives such as workshops and mentor support to innovators in general.
Construct and create "urban living laboratories" where R&D projects can be piloted and skills can be transferred between individuals	• University of Cape Town's Franschhoek Water Hub facilitates the practical training and skills development of students, alongside the development and demonstration of innovative technologies (NSTF, 2016). • *Bridging the water: co-create to learn and experience sustainable strengthening the South African Water Education and Training Capacity'* (OKP-ZAF-10002) is part of the Orange Knowledge Programme (OKP) administered by Netherlands Organisation for International Cooperation in Higher Education (NUFFIC). Living labs in this project will be used to train alumni of Durban University of Technology and University of Cape Town.
Develop multi-disciplinary talent within the RDI environment	• In a WRC funded project a five year programme was developed for interdisciplinary research, conducted by postgraduates and their supervisors from various institutions within South Africa across the disciplines ecology, hydrology and economics. The model was structured in such a manner to not only facilitate interdisciplinary learning for the students but also to transfer knowledge from disciplinary experts (Esler et al., 2016).
To continue to use, where the need arises, online platforms (or hybrid systems) for short courses and conferences even after the COVID-19 pandemic	• The WISA conference held in 2020 was held completely virtual. Advantages, as listed by their Organising Committee, of a virtual platform included; savings due to the elimination of travelling costs; savings for exhibitioners due to the use of an online platform and the opportunity of delegates from different parts of the world to collaborate virtually. From a knowledge perspective the virtual conference provided the opportunity to "attend" all the sessions since registered delegates had unlimited access to all recorded conference sessions, posters and exhibition areas, both during the live conference and online for months after the event was hosted (WISA, 2020).
To continue to use, where the need arises, hybrid/blended learning systems even after the COVID-19 pandemic	• The Independent Institute of Education Monash SA, for example, uses flexible teaching methods for their Postgraduate Diploma in Water Management and MPhil Integrated Water Management courses to enable working professionals to enrol. These methods include face-to-face sessions, online learning, case studies and projects (II EMSA, 2020).

CHAPTER 8: ROADMAP SKILLS MAP SUMMARY FINDINGS

The WRC Water RDI Roadmap (2015-2025) is a high-level planning intervention that facilitates and guides the refocusing of research, reprioritisation of funds, synergising of existing initiatives and ring-fencing of new resources to facilitate a more optimal water innovation system. One of the main pillars and focal areas of the Roadmap is to support high-end human capacity development for water research, development and innovation. The primary focus of this Roadmap's skills development efforts was centred around post-graduate level skills (specifically mapping water-related postgraduate courses, a mandate derived from the DST focus areas) as well as graduate level skills. Highly skilled individuals are key to enabling faster and more effective development and deployment of context-appropriate solutions to water sector challenges. Similarly, training (including short courses) is seen as a key aspect of driving the deployment of new knowledge and innovation into different implementation contexts. The aspect of this study that focuses on research-related and postgraduate skills will be particularly important to inform the WRC and Water RDI Roadmap strategy.

This Water Sector Skills Mapping Study, which is a series of four volumes, managed to address some of the key issues towards updating the Water RDI Capability Map (Volume 1), mapping and analysing the water sector postgraduate training landscape (Volume 2), mapping the RDI relevant short course training landscape (Volume 3) and understanding the water sector skills demand (Volume 4). The following sections describe the objectives of each volume and highlight the relevance of some of the main findings to the Water RDI Roadmap published in 2015.

It should be taken into consideration that the response rates of the respective questionnaires in the four studies ranged from 9.44% (understanding the sector skills demand study) to 25.3% (updated Water RDI Capability Map). However desktop studies, focus group and semi-structured interviews were also conducted for data collection.

8.1 WATER RDI CAPABILITY MAP

The objective of the capability mapping in the current study was to provide insight into where the different water-related RDI disciplinary skills sets lie around the country. The strength of the capability mapping is that it gives information on the different competencies, based on the Water RDI Roadmap clusters and Research Focus Areas (RFAs), which allows for a more focused consideration on how to best support and structure the RDI capability optimally.

The research strength/maturity of RDI capability, was based on the composite score measured at four levels, namely emerging (0-0.2), building (0.2-0.4), established (0.4-0.6) and mature (0.6-1). The RDI maturity was measured based on the number of researchers in an RDI team and the years of experience and highest qualification of the lead researcher/s. Based on the survey results the highest number of RDI activities at 45% takes place in thematic cluster "Increase ability to make use of more sources of water", with the highest number of "mature" institutions observed in this cluster. According to the WRC RDI Roadmap (2015-2025), the highest percentage (38%) of the total investment budget should be allocated to the cluster "Sources". The cluster "Efficient use of water (Agriculture, industry, and consumers") and "Governance, planning and management of supply and demand" also had high percentages of respondents linking their water related RDI activities to these clusters, at 39% and 31%,

respectively. According to the WRC RDI Roadmap (2015-2025), the second highest percentage of the budget (23%) should be allocated to the cluster “Productive use” (“Reduce losses and increase efficiency of productive use”), and 8% should be allocated to “Governance, planning and management of demand” and 6% to “Governance, planning and management of supply”.

The lowest percentage of RDI activities takes place in the thematic cluster “Running the water sector as a smart business” at 12% with the lowest number of institutions with RFAs identified with RDI activities rated as matured. According to the WRC RDI Roadmap (2015-2025) 10% of the total investment required should be allocated to the cluster “Operational Performance” (“Run water as a financially sustainable “business” by improving operational performance”).

In certain cases, there seems to be an alignment between the total investment required in the WRC RDI Roadmap (2015-2025) and the reported water-related RDI activities in the majority of the clusters in the current study. It should however be noted that the figures regarding the investment requirements are based on forecasts. The percentages of the WRC budget spend per cluster are only available in the public domain for the 2015 (Pouris, 2018) and 2016/2017 financial year (WRC, 2017). The Water RDI Roadmap is a ten-year plan which is still in progress until 2025. Therefore, care should be taken when using the investment requirements as stated in the Water RDI Roadmap as an indicator.

The research conducted for the Water RDI Roadmap took place from 2014 to 2015. The water-related RDI landscape in South Africa could have changed during the last few years and is an area for future research. Cluster 5 “Running the water sector as a smart business” is just one example, as stated previously it had the lowest percentage of reported water-related RDI activities. However recent research has shown there are water boards (Ngobeni and Breytenbach, 2020) and water service authorities (Nkabane and Nzimakwe, 2018; Dikgang et al. 2020) that can be operated more efficiently by reducing costs and improving revenue generation. In future the need for RDI activities linked to this cluster could increase and needs to be further investigation.

Research Focus Areas which featured strongly in the reported RDI activities, across the thematic themes, include environment, environmental health and ecosystem functioning, environmental water quality, hydrology and water resources, integrated water resources management, sustainability, wastewater treatment, water and wastewater treatment, water quality and water resources, and water resource management. According to the survey results the study also shows a number of RFAs with no RDI activities which include bioethics, geomembrane linings and covers for potable water storage, non-Newtonian fluid mechanics, ocean wave power, plant life extension technologies, and unsaturated zone.

An additional component of this research focused on the research strength based on bibliometric data (2014-2018) using the total number of different outputs (articles, proceeding papers, reviews, book chapters) as well as average number of citations per item. For a number of institutions where the research maturity during the RDI Capability Mapping Study were rated as emerging, less than 50 publications were produced by these institutions. For institutions that produced high levels of research publications between 2014 and 2018, the results are comparable to some HEIs with RFAs identified at levels of RDI activity rated as “matured”.

8.2 POSTGRADUATE MAPPING STUDY

The main objective of this study was to develop a detailed map of and identify gaps in the current water sector-related postgraduate training (Honours, Masters, PhD) offered at all 27 HEIs in South Africa.

The anticipated RDD outcomes for human capital development in the Water RDI Roadmap (2015) are 215 post-doctoral researchers, 537 doctorates and 805 masters, based on a set of productivity assumptions (WRC, 2015). The current postgraduate study indicated that these anticipated postgraduates can select a water-related postgraduate programme from a comprehensive list of options (107 general degrees and 55 specialised postgraduate degree programmes). Furthermore, the options of HEIs which postgraduates could select from to obtain their degrees are also comprehensive with 21 of the 27 HEIs offering water-related postgraduate programmes. Specialised water degrees are only evident at a number of HEIs [University of KwaZulu-Natal (UKZN), Limpopo University (LU), Independent Institute of Education Monash SA (IIE MSA), North West University (NWU), Rhodes University (RU), Stellenbosch University (SU), University of Cape Town (UCT), University of Free State (UFS), University of Pretoria (UP), University of the Western Cape (UWC), University of Venda (UNIVEN), University of the Witwatersrand (WITS), University of Zululand (UNIZULU)] as opposed to universities of technology. There are no specialised water-related programmes on offer at the following HEIs: Central University of Technology (CUT), Durban University of Technology (DUT), Mangosuthu University of Technology (MUT), Nelson Mandela Metropolitan University (NMMU), Sefako Makgatho Health Sciences University (SMU), Sol Plaatje University (SPU), Tshwane University of Technology (TUT), University of Fort Hare (UFH), University of Johannesburg (UJ), University of Mpumalanga (UMP), University of South Africa (UNISA), Vaal University of Technology (VUT) and Walter Sisulu University (WSU). The highest number of specialised programmes are offered by UCT followed by UP, with UCT and UKZN offering the broadest range of specialised courses in terms of disciplines.

General degrees with the opportunity to specialise in water are offered at: Cape Peninsula University of Technology (CPUT), CUT, DUT, LU, NMMU, NWU, RU, SU, UCT, UFS, UFH, UJ, UKZN, UP, UNISA, UNIVEN, WITS, UWC, UNIZULU and VUT. There are no general water degrees offered at IIE MSA, MUT, SMU, SPU, TUT, UMP and WSU. UCT and SU have the largest offering of general degrees. The majority of general degrees are in the Environmental Sciences followed by Engineering and the Built Environment with the least number of general postgraduate degrees being in Education and Medicine/Public Health.

The largest number of water-related specialised postgraduate programmes are in the disciplines of Environmental Sciences followed by Engineering and the Built Environment; with the least programmes offered in Education, Commerce, Social Science/Humanities and Medicine/Public Health. The overwhelming majority of specialised courses include Hydrology and/or Water Resource Management. Nine specialised Honours courses were identified mostly in the science discipline; however, it is acknowledged that four-year Bachelors degree programmes in other faculties such as Engineering, the Honours program is classified as part of the undergraduate degree.

The findings are in broad alignment with research conducted by Pouris (2018) who indicates that UKZN, UP and UCT published the highest number of water research articles between 2014 and 2018. UJ, however, while identified by Pouris (2018) as an HEI with prolific water research activity, did not emerge in this study as having a significant number of postgraduate offerings. UCT, UKZN and UP are also identified in Deliverable 2 as having mature and established research strength.
Cluster “Governance, planning, and management of supply and demand” emerged as being the strongest thematic cluster by having the largest number of RFAs mapped to all the postgraduate programmes. This was followed by Clusters “Increase ability to make use of more sources of water” and “Efficiency use of water (Agriculture, industry, and consumers)” with a similar RFA count. Cluster “Adequacy and performance of supply infrastructure and operational performance [Built infrastructure)”/”Adequacy and performance of supply infrastructure and operational performance (Ecological infrastructure / ecosystems)” was the weakest cluster with the fewest RFAs. The data from

the water-related RDI capability mapping, postgraduate mapping and short course mapping studies were compiled to draw a comparison between the different clusters in Table 16.

Findings from the focus group interviews made important observations regarding the level of support for postgraduates which could influence the anticipated human capital development outcomes of the Water RDI Roadmap (2015). The lack of a consistent funding source for the water industry was noted by interviewees as a deterrent for postgraduate enrolments. Interviewees also noted that the restructuring of the National Research Foundation (NRF) over the last 2 years, for instance, has affected the availability of funding for many students wanting to enrol for postgraduate research. Academic staff plays an important role in supervisory capacity of postgraduates as well as providing expertise in their respective research activities. Therefore a lack of depth or succession plans, noted during the interviews, should academic staff leave academia is also challenge which could impact human capital development negatively. This is in alignment with DST (2017) where it is noted that while postgraduate enrolment rates have increased, there has been no corresponding increase in the number of academic staff.

The objective of the current study was to identify all water-related postgraduate programmes offered by HEIs in South Africa. In future the supply of postgraduates graduating with a water-related degree could be investigated by monitoring the number of postgraduates obtaining degrees from all the water-related postgraduate programmes identified in this study. The information obtained could then be compared to the targets included in the Water RDI Roadmap for further evaluation. However the following preliminary and exploratory scenarios are described to investigate whether the identified water-related postgraduate programmes will provide sufficient support for the Water RDI Roadmap to reach its postgraduate targets using the number of postgraduates as the example. As stated earlier, the Water RDI Roadmap has a target for 537 doctorates during a ten year period (2015-2025). The study identified 14 specialised and 91 general doctoral programmes. Therefore to reach the target in the ten year period, for example, each general doctoral programme should have five successful candidates obtaining their general degrees with a focus on water and each specialised doctoral programme should have six successful candidates obtaining their specialised degree. However if every general doctoral programme have four successful candidates obtaining their degrees with a focus on water, it means that each specialised degree must then have 13 successful candidates during the ten year period.

This study also identified strategic and operational gaps in the current water sector-related postgraduate training (Honours, Masters, and PhDs). By addressing these gaps and investigating the recommendations included in this study, the level of postgraduate support could be improved to assist the Water RDI Roadmap with reaching its postgraduate targets.

8.3 SHORT COURSE MAPPING STUDY

The objective of the water sector Short Course Mapping Study was to develop a high-level overview and map of available, quality-assured, RDI-relevant water-related short courses in South Africa. Further outcomes of the deliverable are to facilitate alignment of short courses offered by HEIs and other institutions and enable opportunities for more focused cooperation and partnerships in training and development between HEIs and water sector organisations. The target audience included stakeholders within all of South Africa's 27 HEIs, professional bodies, and specialist research and innovation organisations.

Targets for RDI-relevant water-related short courses are not present in the Water RDI Roadmap (WRC, 2015). Results from this study indicate that short courses in the water-related RDI environment could

serve as a powerful tool of knowledge transfer and the inclusion of targets for short courses in the Water RDI Roadmap should be considered. This recommendation is made since 134 RDI-relevant water-related short courses have already been identified in this study through a desktop study and online questionnaire. As these courses are offered by HEIs (54%), professional bodies (28%) and research and innovation specialists (19%) it is assumed that the short course facilitators have the required expertise to present the content of the respective short courses.

The mapping of the short course programme findings – linking to the WRC (2015) thematic clusters of needs and interventions relating to supply and demand for the water community, revealed that the outright majority of short course offerings are linked to Cluster “Governance, planning and management of supply and demand” and Cluster “Adequacy and performance of supply infrastructure and operational performance (Built Infrastructure /Ecological Infrastructure /Ecosystems”. The fewest number of short course offerings are linked to Cluster “Running the water sector as a smart business” and Cluster “Monitoring and metering”.

Lastly, the study has identified operational and strategic gaps in the available RDI-relevant water-related short courses. By addressing these gaps and investigating the recommendations included in this study the effectiveness and sustainability of using short courses as a tool of knowledge transfer in the water-related RDI environment could be improved.

Data from the water-related RDI capability mapping, postgraduate mapping and short course mapping studies were compiled to draw a comparison between the different clusters (Table 16).

Table 16: Comparison between the results of the water-related RDI capability mapping, postgraduate mapping and short course mapping studies

	RDI Capability Map	Postgraduate Mapping Study	Short Course Mapping
Clusters with the "strongest" activities			
Cluster "Increase ability to make use of more sources of water"	Highest number of RDI activities at 45% takes place in this thematic cluster, with the highest number of "mature" institutions observed. **WRC RDI Roadmap (2015-2025) target – the largest percentage (38%) of the total investment budget should be allocated to the cluster "Sources".**	This cluster emerged as being the 2nd strongest thematic cluster, together with Cluster "Efficient use of water (Agriculture, industry and consumers") (had the second highest number of RFAs mapped to all the postgraduate programmes). **WRC RDI Roadmap (2015-2025) target – the largest percentage (36%) of Masters and PhD student requirement should be allocated to this cluster.**	Second highest percentage of short courses mapped onto this cluster (9%).
Cluster "Efficient use of water (Agriculture, industry and consumers).	Second highest percentage (39%) of respondents linking their water related RDI activities to this cluster. **WRC RDI Roadmap (2015-2025) target – the second largest percentage (23%) of the total investment budget should be allocated to the cluster "Productive use" ("Reduce losses and increase efficiency of productive use).**	This cluster emerged as being the 2nd strongest thematic cluster, together with Cluster "Increase ability to make use of more sources of water" (had the second highest number of RFAs mapped to all the postgraduate programmes). **WRC RDI Roadmap (2015-2025) target – the second largest percentage (29%) of Masters and PhD student requirement should be allocated to this cluster.**	Only 6% of short course offerings were mapped onto this cluster.
Cluster "Governance, planning and management of supply and demand"	Third highest percentage (31%) of respondents linking their water related RDI activities to this cluster. **WRC RDI Roadmap (2015 2025) target – 8% investment budget should be allocated to "Governance, planning and management of demand – and 6% of investment budget to "Governance, planning and management of supply (14% in total).**	This cluster emerged as being the strongest thematic cluster by having the largest number of RFAs mapped to all the postgraduate programmes. **WRC RDI Roadmap (2015-2025) target – clusters with 6% of student requirement to "Governance, planning and management of demand – and 6% of student requirement to "Governance, planning and management of supply (12% in total).**	Highest reported percentage, together with Cluster "Adequacy and performance of supply infrastructure and operational performance", of short courses mapped onto this cluster (41%).
Cluster with the "weakest" activities			
Cluster "Running the water sector as a smart business"	The lowest percentage RDI activities takes place in this thematic cluster at 12% with the lowest number of institutions with "mature" RDI activity observed. **WRC RDI Roadmap (2015-2025) target 10% of the total investment required should be allocated to the cluster "Operational Performance" ("Run water as a financially sustainable "business" by improving operational performance").**	This cluster had the second lowest number of RFAs mapped to all the postgraduate programs. **WRC RDI Roadmap (2015-2025) target – 9% of Masters and PhD student requirement should be allocated to the cluster "Operational Performance" ("Run water as a financially sustainable "business" by improving operational**	The lowest percentage of short course offerings are linked to this cluster (1%).

8.4 SKILLS DEMAND STUDY

The objective of the skills demand study was not only to investigate the skills demand in the water-related RDI environment but in the wider water sector. The specific skills in demand, as listed in Chapter 6, are therefore not directly comparable to the clusters, disciplines and RFAs used in the supply side studies. However using a holistic view the following general observations were made when comparing the results of the skills demand study and the studies conducted on the supply side:

- The skills "new business development", "understand the internal and external regulatory environment", "understand the business environment in which the company operates" and "commercial awareness" were listed as skills in demand according to the survey results. It is therefore important to note that in comparison to the other clusters, the Cluster "Running the water sector as a smart business" had lower reported percentages of RDI activities, postgraduate courses and short courses linked to this cluster. Also in the postgraduate mapping study the least number of specialised postgraduate programmes were reported in Commerce along with Education, Social Sciences/Humanities and Medicine/Public Health.
- Other major skills gaps identified for the water-related RDI environment were the lack of social sciences and socio-ecological systems within the water-related RDI environment. In the water-related RDI capability mapping study only 5% of water-related RDI activities were reported for the research discipline Social Sciences and Humanities. In the postgraduate mapping study the least number of specialised postgraduate programmes were reported in Social Sciences/Humanities along with Education, Commerce and Medicine/Public Health.
- The demand of leadership skills in the water sector was also an important trend noted in the skills demand study. The only supply side study in the project linked to leadership skills was the short course mapping study. The objectives of two of the courses reported in the study were linked to leaderships skills, namely: National Certificate: Water and Wastewater Process Control (NQF Level 3) (CPUT) and Water Governance for Water Leaders (SU).
- As already noted, from a supply perspective the postgraduate mapping study identified water-related postgraduate programmes offered by HEIs in South Africa but did not monitor the number of individuals graduating from these respective programmes (current supply of postgraduates). Similarly, the aim of the demand side skills study was to investigate what specific skills the water sector requires, and not specifically the number of postgraduates the water sector absorb. However, as noted during the focus group interviews, due to a number of reasons, most of the organisations in the water sector employ doctoral graduates less frequently as these professionals tend to go into research specific fields. Therefore, if it is envisioned that a percentage of the postgraduate targets in the Water RDI Roadmap should be employed within the wider water sector, it is a possible concern and should be further investigated. Furthermore, the National Development Plan of 2030 aims to significantly increase the number of PhD graduates in South Africa and aims to make this qualification more desirable for prospective graduates. This also prompts the need for future research in the employment prospects of PhDs with a water-related degree in the private sector as well as more permanent positions in academia.

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APPENDICES

APPENDIX 1: LIST OF WATER-RELATED OCCUPATIONS (JOB TITLES) INCLUDED IN THE STUDY

OFO Code	Water-related occupation (job title)
2019-214905	Agricultural Engineer (Irrigation Engineer)
2019-214906	Agricultural Engineering Technologist (Irrigation Engineering Technologist)
2019-314201	Agricultural Technician (Irrigation Technical)
2019-214501	Chemical Engineer
2019-311601	Chemical Engineering Technician
2019-214502	Chemical Engineering Technologist (Environment (Water, Air, Soil) Technologist)
2019-211301	Chemist
2019-214201	Civil Engineer (Construction Engineer)
2019-214201	Civil Engineer (Hydraulics Engineer)
2019-214201	Civil Engineer (Water and wastewater Engineer)
2019-311201	Civil Engineering Technician
2019-214202	Civil Engineering Technologist (Construction Technologist)
2019-214202	Civil Engineering Technologist (Hydraulics Technologist)
2019-214202	Civil Engineering Technologist (Water and Wastewater Technologist)
2019-243201	Communication Coordinator (Water Liaison Practitioner)
2019-133103	Data Management Manager (Data Processing Manager or Data Operations Manager)
2019-215101	Electrical Engineer
2019-215102	Electrical Engineering Technologist
2019-311401	Electronic Engineering Technician (Instrumentation Technician and Telemetry Technician)
2019-132104	Engineering Manager (Engineering Maintenance Manager)
2019-214302	Environmental Engineer (Water Resource Specialist)
2019-134901	Environmental Manager (Sanitation Programme Manager)
2019-134901	Environmental Manager (Water Resource Management Practitioner)
2019-134901	Environmental Manager (Water Resource Manager)
2019-314102	Environmental Science Technician (Environmental Technical Officer)
2019-314102	Environmental Science Technician (Water Pollution Control Officer)
2019-213302	Environmental Scientist (Environmental Officer)
2019-213302	Environmental Scientist (Environmental Research Scientist)
2019-213302	Environmental Scientist (Water Use Specialist)
2019-211401	Geologist (Hydrogeologist)
2019-351302	GIS Technician (GIS Operator/Specialist)
2019-211406	Hydrologist
2019-111203	Local Authority Manager (Water Services Provider Manager)
2019-214401	Mechanical Engineer (Mechatronics Engineer)
2019-311501	Mechanical Engineering Technician
2019-214402	Mechanical Engineering Technologist (Maintenance Technologist)
2019-213108	Microbiologist
2019-121905	Programme or Project Manager
2019-216502	Surveyor
2019-121910	Water Asset Manager
2019-311217	Water Control Officer
2019-313203	Water Process Controller (Water Works Management Practitioner)

2019-134918	Water Production and Supply Manager
2019-213306	Water Quality Analyst (Wastewater Treatment Officer/Technician)
2019-213306	Water Quality Analyst (Water Quality Technician)
Other	Please specify

APPENDIX 2: STAKEHOLDERS WHO RESPONDED TO THE QUESTIONNAIRE:

Name of organisation or institution (Department)
Agricultural Research Council (Smallholder Farmer & Enterprise Development, Agricultural Engineering, Irrigation and drainage engineering)
Bosch Capital
Cape Nature (Biodiversity Capabilities)
Cape Peninsula University of Technology (Department of Engineering and Built Environment)
Clearedge Projects
Consultant (Self-employed)
De Zalze Winelands Golf Estate (Environmental)
Delta H (Hydrogeology)
Department of Environmental Affairs and Development Planning (Pollutions and Chemical Management)
Department of Water and Sanitation (Options Analysis, Planning)
Drakenstein Municipality
Durban University of Technology (Horticulture)
Envirosource (Water and Environment)
EWSETA (Skills Development Department)
Free State Agriculture
Inkomati-Usuthu Catchment Agency (Resources Planning and Operations)
Institute of Natural Resources (Adaptation and Resilience)
Magalies Water (Corporate Services and Human Resources)
Mintek (Biotechnology)
Mossel Bay Municipality (Water and Sanitation)
National Institute for Occupational Health (Immunology and Microbiology)
Natures Valley Trust
Palmer Development Group (Pty) Ltd (N/A)
SDW Engineers
South African Weather Service (Research and Development)
Rhodes University (Institute for Water Research)
Stellenbosch University (Centre for Geographical Analysis, Civil Engineering Department, and Conservation Ecology and Entomology)
University of Cape Town (Future Water Research Institute)
University of KwaZulu-Natal (Centre for Water Resources Research)
University of Pretoria (Department of Biochemistry, Genetics and Microbiology)
University of Fort Hare (SAMRC Microbial Water Quality Monitoring Centre-Department of Biochemistry and Biochemistry)
University of the Free State (Institute of Groundwater studies)
University of the Western Cape (Institute for Microbial Biotechnology and Metagenomics)
Water Institute of South Africa (Training and Accreditation)
Winetech
WSM Consulting (Pty) Ltd
Wynland Water (N/A)

APPENDIX 3: ORGANISATIONS THE INTERVIEWED STAKEHOLDERS WERE EMPLOYED AT DURING THE COMPLETION OF THE FOCUS GROUP INTERVIEWS

Organisation
Focus Group Interviews
AgriSA Water Desk – Institutional Management
Amatola Water
Breede-Gouritz Catchment Management Agency
City of Tshwane Municipality
Department of Water and Sanitation, National
Department of Water and Sanitation, Provincial
Ekurhuleni Metropolitan Municipality
Elsenburg
Emanti Management (Pty) Ltd
ESKOM
eThekwini Metropolitan Municipality
Garden Route District Municipality
George Municipality
Golder Associates Africa (Pty) Ltd
Institute of Natural Resources (Participant provided)
Karstens Boerdery
Lepelle Water
Mossel Bay Municipality
Northern Cape Mining Industries
SA Association of Water Users Associations
SASOL
SJ De Wet Consulting Services
SOILL
Umgeni Water
Water Group Holdings (Pty) Ltd
Future Skills Interviews
Isle Utilities
South African Sanitation Acceleration Programme (SASTEP)
University of Cape Town Future Water Institute
University of Stellenbosch Centre for Collaboration in Africa
Water Technologies Demonstration Programme (WADER)