CONSIDERATION OF THE VALUE OF ESTUARINE ENVIRONMENTS IN GROUNDWATER MANAGEMENT

Case study of the Moore River Estuary

Report by Patricia Ngati

Workplace supervisor: Adam Green

ECU supervisor: Prof. Angus Morrison-Saunders

Acknowledgments

I would like to thank my workplace supervisor, Adam Green, for his keen interest in this project. I am thankful for his continuous guidance, support and encouragement. I would also like to thank my ECU supervisor, Prof. Angus Morrison-Saunders for his enthusiasm in this project, his advice and for always responding to my questions so promptly.

My sincere appreciation to all the people who willingly gave up their time and completed the surveys, as well as the interviewees who so generously offered their time and knowledge. Thank you. This study would not have been a success without you.

I would also like to thank the Department of Water and Environmental Regulation for providing the resources required to carry out this project. Thank you to everyone who offered their advice and support to make this project a success.

Special thanks to all the organisations that provided tourism and economic data to be used in this project: Guilderton Caravan Park, Tourism Western Australia, Country Values Holiday Homes, Guilderton Visitor Centre and Gingin Shire.

List of interviewees

David Rickson – President, Gingin Water Group; long term Guilderton resident
John Prince – Former President, Guilderton Community Association; author of 'Secret No Longer, The Story of the Guilderton Community Association 1960-2012'; long term Guilderton resident
Linda Johnson – Friends of the Moore River Estuary; Gingin Water Group; long term Guilderton resident
Phil Cook – Moore River Cruises; long term Guilderton resident
Barry and Patricia Sykes – Long term Caraban residents
Ian (Sam) Collard – President, Gingin Shire; long term Guilderton visitor and current resident
Geoffry Liddelow – Manager, Guilderton Caravan Park

Executive summary

The Moore River Estuary is a pristine ecosystem that has maintained its healthy state despite increased recreational use over the years and agricultural activities in its catchment. It is located between two groundwater allocation plan areas: The Gingin groundwater allocation plan area to the north and the Gnangara groundwater allocation plan area to the south. Groundwater discharge into the estuary is believed to be vital for the maintenance of its healthy condition. This study was carried out to establish the value of the Moore River Estuary to the local community and visitors, and the condition that needs to be maintained to continue to provide this value. The results of this study will be useful in informing future groundwater management in the Gingin and Gnangara groundwater allocation plan areas by the Department of Water and Environmental Regulation.

The main methods used to achieve the aims of this study were interviews with key stakeholders and surveying of recreational users of the Moore River Estuary. Data on visitor numbers to the Moore River Estuary and annual revenue to businesses was collected and used to provide an understanding of the economic value of the Moore River Estuary. The findings from this study were compared to literature from studies that had been previously conducted on the estuary.

The results of this study showed that the users of the Moore River Estuary were generally happy with its current condition. Survey respondents drew attention to three key factors that should be well managed to ensure community and visitor satisfaction, and maintain the current condition of the estuary. These were:

- Maintenance of the current appearance and smell of the water body
- Maintenance of water quality suitable for human recreation
- Continued presence of healthy fish populations

Groundwater discharge is important in maintaining the current condition of the estuary, especially as the climate continues to dry and streamflows from Gingin Brook and Moore River reduce. The following recommendations have therefore been made to assist in groundwater management in the estuary:

- Further research should be conducted to build on this study
- Hydrogeological investigations should be conducted to provide a better understanding of the groundwater-surface water interaction in the Moore River Estuary
- The community and visitors should be educated on the effects of artificially opening the sandbar

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1. Introduction

I undertook a three-month work placement at the Department of Water and Environmental Regulation (DWER) in partial fulfillment of the requirements for a Master of Environmental Science. During my work placement, my main task was to undertake a project of relevance to the Environmental Water Planning section of DWER.

This report is a summary of the activities undertaken during the work placement, the role of the project undertaken within the Environmental Water Planning section of DWER, the project aims and the methods used to achieve them, the findings of the study and recommendations for future work.

1.1 Background of the host organisation

The Department of Water and Environmental Regulation (DWER) was formed on 1st July 2017 after the merging of the former Department of Environment Regulation, Office of the Environmental Protection Authority and Department of Water, with the intention of providing a synchronised approach to the regulation of water and environment in the state (Department of Water and Environmental Regulation, 2018). It is responsible for managing and regulating Western Australia's environmental and water resources. The Environmental Water Planning section of the department sits within the Water Allocation Planning branch and plays a key role in protecting water-dependent environments in the state through input into water allocation plans. Water allocation plans help manage the state's surface water and groundwater resources by outlining how much water is available for use and how much needs to remain in the system to protect water-dependent environments and ensure the sustainability of the resource, as detailed under the Rights in Water and Irrigation Act (Department of Water [DoW], 2011).

The development of a water allocation plan takes several years, is a joint effort by different branches across the department and involves significant stakeholder consultation. It is a multi-disciplinary task and involves assessment of the hydrology, geology, environmental water requirements, water use and demands, climatic trends, and social and economic issues related to water use in a region (DoW, 2011).

The 'Consideration of the value of estuarine environments in groundwater management - Case study of the Moore River Estuary' project was undertaken within the Environmental Water Planning section of DWER. As this was a work placement project, my DWER supervisor, Adam Green, was involved in all stages of the interview and survey development, and data collection, providing guidance where needed.

1.2 Background of the project

The Moore River Estuary is classified as a wave-dominated estuary (Moore River Estuary, n.d.). Despite extensive agricultural practices in its catchment, the Moore River Estuary, unlike other estuaries in the region, has not displayed any visible signs of eutrophication (Anderson, 2004). It is because of this serene state that tourists visit the region each year to enjoy activities such as camping, fishing, swimming and kayaking, and in turn contribute to the region's economy (The Present, n.d.). This is evident as the population of Guilderton town swells from approximately 172 to 3,000 during the summer holidays (Guilderton Visitor Centre, n.d.). Some of the unique attractions to the estuary are water-based recreational activities such as boating, paddling, swimming and fishing, as well as sandboarding at a sand sheet known as 'The Desert' (Friends of the Moore River Estuary and Bushland, 1995).

The presence of good quality water in the Moore River Estuary is critical to maintaining its pristine nature. Water flow into the estuary is maintained by groundwater discharge as well as stream inflows from the Moore River and Gingin Brook (Cousins, 2002). The effects of the drying climate in south-west Western Australia have already been observed with reduced stream flows, and parts of Gingin Brook are now dry in

summer (DoW, 2015a). Groundwater discharge to the estuary is thought to be critical to maintaining the water-dependent values the estuary provides, particularly as the climate dries and stream inflows continue to decline (Adam Green [DWER Scientific Officer], pers. Comm.). Areas of groundwater discharge are visible along the estuary as seeps along its banks. These seeps are especially apparent when the sandbar at the river mouth is breached and water levels are low. Seeps can be observed at the following sites along the estuary: Silver Creek, The Desert, Caraban Rocks and Waterville road (Cousins, 2003) (Figure 1). Whilst streamflow gauging stations on the Moore River and Gingin Brook just upstream of their confluence provide detailed records of daily streamflow, little is known about the role of groundwater in maintaining water flows into the estuary. An improved understanding of the role of groundwater-surface water interaction in maintaining the health of the Moore River Estuary will be important in the future management of groundwater allocations in the surrounding agricultural areas.

The Moore River Estuary and Gingin Brook streamlines separate the northern extent of the Gnangara groundwater allocation plan area from the southern extent of the Gingin groundwater allocation plan area. According to the Gingin groundwater allocation plan (DoW, 2015a), agriculture and horticulture are major land use activities in the Gingin area, including the areas around the Moore River Estuary. The growth of these industries in combination with the effects of a drying climate is placing increased pressure on groundwater resources. To enable effective water management, decision-makers need to weigh up the losses and benefits associated with water abstraction, economic development and alteration of ecosystem services. It is therefore necessary to understand how the estuary is changing with climate and land use activities, and the condition that will continue to provide for its social use. The findings from this project will inform future groundwater management decisions in the Gingin and Gnangara groundwater allocation plan areas by determining the social value the estuary provides to the local community and visitors. In particular, it will attempt to describe the role of freshwater inflow (groundwater and surface water), water level, water quality and appearance of the estuary in maintaining this value, and the contribution this makes to the local economy. This information will be considered by the department when making long term water planning decisions around water allocation in the Gingin and Gnangara groundwater allocation plan areas due to the groundwater-surface water interaction around the estuary.

1.3 Study area

This study took place at the Moore River Estuary, located in the south-west of Western Australia, in the town of Guilderton, about 75 km north of Perth. The estuary extends from the mouth of the river to Boobabbie Bridge (Figure 1). The project study area extended slightly further upstream to include a popular picnic area and overnight camping spot just above Indian Ocean Road as shown in figure 1 below.

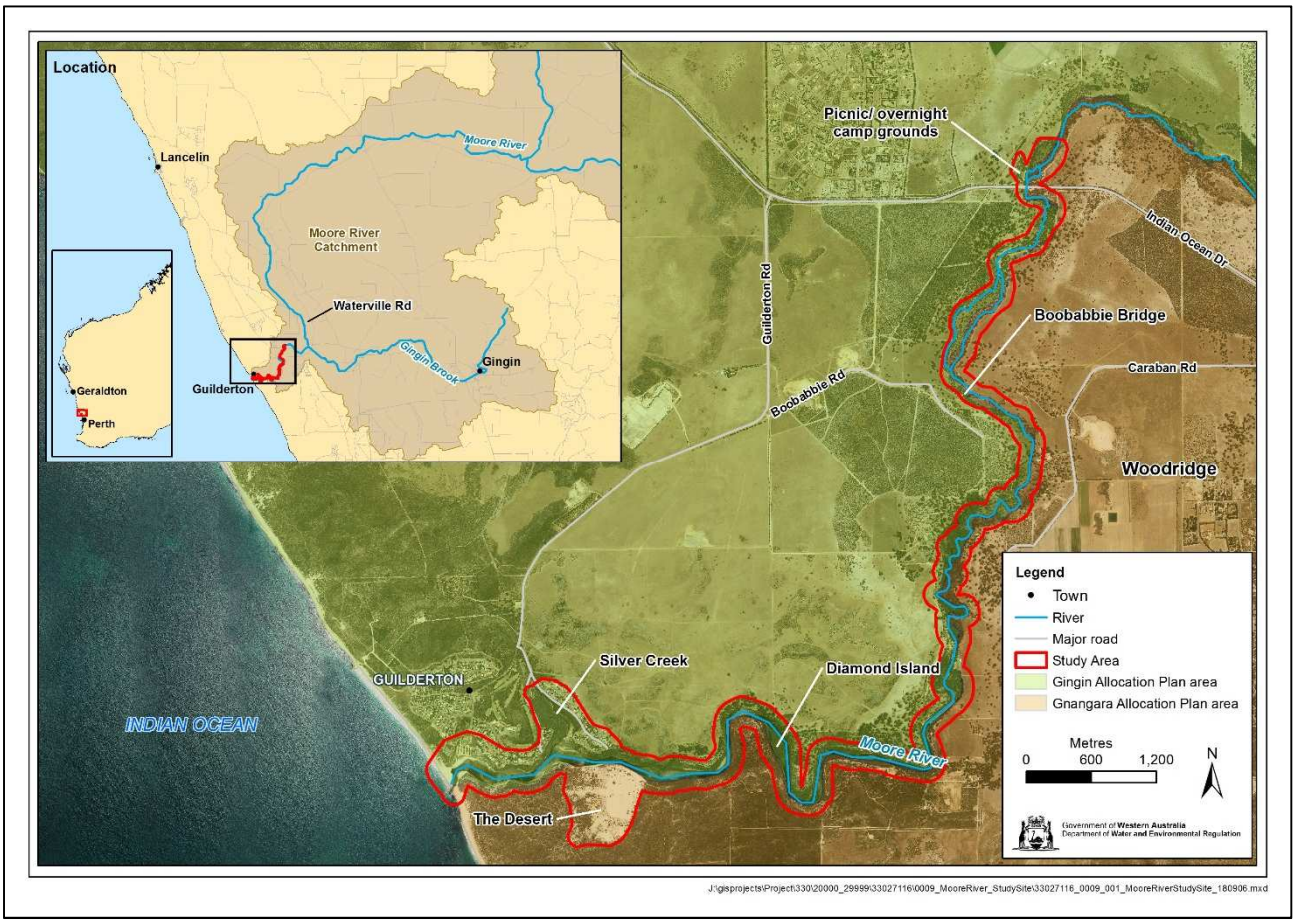

Figure 1: Map of study area (Source: Department of Water and Environmental Regulation)

1.4 Aims

Personal Aims

- To gain confidence in the application of knowledge I have gained in my years of study in Kenya and Australia

Project Aim

- To identify the value of the Moore River Estuary to the local community and visitors, and the condition that needs to be maintained to continue to provide this value

Research questions

- What are the social, environmental and economic values provided by the Moore River Estuary and how have they changed over time?
- How important is the condition of the Moore River Estuary to maintaining its social and economic value?
- What is the desired future state of the Moore River Estuary to the local community and visitors?

2. Overview of the Work Integrated Learning

My work placement at DWER started on 31st July, 2018 and ended on 9th November, 2018. I was required to be present at work every week day, from 8:30 am to 4:30 pm. I attended the scheduled Friday lectures at ECU Joondalup and went to work after the lectures.

In the first month of my work placement, I reviewed literature, familiarised myself with the study area and the Environmental Water Planning section of DWER and informed stakeholders about the project. The second month was set aside for surveys and interviews and I analysed data and wrote this report in the third month.

A summary of the daily work schedule showing the major activities undertaken during this work placement is presented in Appendix A.

3. Methods

Valuation of estuaries is a new concept which has only been recently adopted by countries such as Australia, South Africa and the USA (Adams, 2014). Inflow, resource and condition-based methods were previously used to determine estuarine environmental water requirements but more recent methods use a holistic approach, which considers the ecosystem as well as its stakeholders (Adams, 2014). Close (2005) recommended the BAFFLER (Bayesian Adaptive Framework for Flows to Maintain Estuarine Resources) framework for determination of ecological water requirements of the Hill River and Moore River estuaries. Some of the initial steps recommended by Close (2005) include classification of the estuary, establishment of its values and uses, assessment of the present condition and the desired future state and stakeholder consultation. This project followed these key steps to answer the research questions, using the methods discussed below.

3.1 Desktop analysis of available literature

Literature on the social, economic and environmental values of the Moore River Estuary was reviewed to help answer the research questions and assist in designing of the interview and survey questionnaires. Several studies were conducted on the Moore River Estuary and surrounding regions between the late 1990s and early 2000s. These studies were valuable in providing an insight into the condition of the estuary over time as well as its use. The results of the survey and interviews in this study were compared against findings from the reviewed literature.

A brief summary of some of the literature on the Moore River Estuary that was reviewed is provided in Table 1 below.

Table 1: Summary of reviewed literature in the Moore River Estuary

Summary	Author
A report on the effects of the closing and opening of the sandbar on the water quality in the Moore River Estuary.	(Anderson, 2004)
A report on a survey conducted to understand the effect of human activities of the Moore River Estuary, with recommendations for a management plan for the estuary.	(Black, 1999)
A summary of water sampling data in the Moore River Estuary and surrounds to provide an understanding of its hydrodynamics.	(Cousins, 2002)
A report on the physical, nutrient and biological condition of the Moore River Estuary to understand its ecological health, and recommendations for management.	(Cousins, 2003)
A report on history of geomorphological changes in the Moore River Estuary, backed by anecdotal evidence.	(Grimes & Eliot, 1998)
A brochure handed out to visitors at the Guilderton Visitor Centre providing information on the estuary and its value to the community.	(Guilderton Visitor Centre, n.d.)
An action plan highlighting the issues in the Lower Moore River and providing recommendations to restore the natural environment in the Moore River and guide development.	(Siemon, 2000)
A study of the groundwater-river interaction in the Moore River. This report provided an understanding of the aquifers in the Moore River as well as the gaining and losing reaches of groundwater along the river.	(Stelfox, 2001)
A newsletter addressed to the community summarising studies that had taken place in the Moore River and recommendations for future management.	(Water and Rivers Commission, 2000)
A study of the type and distribution of sediments in the Moore River Estuary and recommendations for management of sedimentation problems in the estuary.	(Wilson & Eliot, 2000)

3.2 Semi-structured interviews

Semi-structured interviews were conducted with key stakeholders with a close and long-term association with the Moore River Estuary. The selected participants had a deep understanding of the Moore River Estuary and shared their knowledge on long term changes they had observed regarding its condition and recreational use. It was necessary to conduct these interviews as some of the research questions required a long term understanding of the estuary to answer them. This was the case where information on long term changes or observations regarding the condition of the estuary was required.

Participants were selected through existing stakeholder relationships with DWER (e.g. Friends of Moore River Estuary and Gingin Water Group) and snowball sampling. The key stakeholders who were interviewed were asked to suggest other key informants who might have had useful information relating to the study. Seven participants were interviewed. Gillham (2000) recommends that since interviews can be time-consuming, both for the interviewer and the interviewee, they should only be used when the information required can be obtained from few, key interviewees who are easily accessible, as was the case for this study. Semi-structured interviews were selected as the most appropriate form of data collection for these key stakeholders to allow them to explain their views while providing comparable

qualitative data.

Most of the information was obtained through open-ended questions and the participants were allowed to give detailed explanations of their answers. A list of indicative interview questions and the research questions they answered is presented in Table 2 below and the interview questions, as presented to the interviewees, are presented in Appendix B.

Table 2: Summary of interview questions presented to seven key stakeholders

Examples of interview questions and the research questions addressed
Research question 1: What are the social, environmental and economic values provided by the Moore River Estuary and how have they changed over time? • In your opinion, what makes the estuary such a special and unique place? • Have you observed any changes to the recreational use of the estuary, tourism or visitor numbers over time?
Research question 2: How important is the condition of the Moore River Estuary to maintaining its social and economic value? • What do you think is the biggest threat to the social value the estuary provides? • How do you think a deterioration in the condition of the Moore River Estuary will impact its social value and consequently visitor numbers to the area?
Research question 3: What is the desired future state of the Moore River Estuary to the local community and visitors? • Are you satisfied with the current condition of the estuary? If not, was there a time in the past when you were more satisfied? • What do you think is the biggest threat to the long term health and condition of the estuary?

The data obtained from interviews was analysed by hand-coding. The results from each interview were summarised in tables. Themes were identified through pawing, a method described by Ryan and Bernard (2003) as reading through text multiple times, using different colours of highlighter pens to mark themes as they emerge. Word repetitions were also used to identify themes such as social values, changes over time and desired condition. This method of thematic coding is consistent with that explained by Creswell (2014) and Gibbs (2007).

3.3 Questionnaires

A study by Black (1999) showed that the Moore River Estuary attracts visitors who mostly stay at the Guilderton Caravan Park. This however may have changed with the increase in rental properties in Guilderton. Others are usually day-visitors who visit the estuary to participate in recreational activities such as boating, fishing, sandboarding and swimming. Questionnaires were distributed on the long weekend of 21st-24th September 2018 at popular recreational sites in the study area such as the overnight camp grounds above Indian Ocean Drive, the foreshore, Guilderton jetty, Guilderton Visitor Centre, Silver Creek, Caraban boat launch and fishing and picnic spots along walk trails opposite 'The Desert'. As this weekend coincided with the start of school holidays, there was a large number of visitors at the estuary. Questionnaires were distributed to respondents at these sites through convenience sampling, a sampling method described by Patton (1990) as the making of decisions on who to sample according to ease of access. The population consisted of a mix of local residents and visitors. The questionnaires were distributed in person, guiding the participants through the questions.

Local businesses such as the Guilderton General Store, Guilderton Country Club and the Guilderton Caravan Park as well as a local resident and an active member of the community group 'Friends of the

Moore River Estuary' were asked to distribute questionnaires to local residents and visitors at the estuary. This sampling technique is known as snowball sampling.

The questionnaires had questions relating to the activities undertaken by the respondents at the Moore River Estuary, the water levels and water quality required to support these activities, their frequency of visits and the desired state for their future use of the estuary. A total of 70 questionnaires were completed. A list of indicative questions is presented in Table 3 below and the full questionnaire distributed to respondents is presented in Appendix C.

Table 3: Summary of survey questions presented to respondents

Examples of survey questions and the research questions addressed
Research question 1: What are the social, environmental and economic values provided by the Moore River Estuary and how have they changed over time? • What activities do you like to do at the Moore River Estuary? • Have you noticed any change in the condition of the Moore River Estuary over the time you have been visiting?
Research question 2: How important is the condition of the Moore River Estuary to maintaining its social and economic value? • What is it about the water in the estuary that allows you to use it the way you do? • Please rate the following in order of importance for your enjoyment of the estuary (Appearance, water quality for human recreation, overall water level or depth at location of use, nice riverbank vegetation, presence of fish in the estuary)
Research question 3: What is the desired future state of the Moore River Estuary to the local community and visitors? • Was there a time in years past when you were happier with the condition of the estuary? • What change in the condition of the estuary would stop you from coming to Guilderton (visitors) or enjoying the estuary (local residents)?

Data collected through the questionnaires was entered in Microsoft Excel spreadsheets. The respondents' answers to each question were coded and analysed using frequencies and summaries.

3.4 Collation of tourism data

Data on visitor numbers to the Moore River Estuary was collected from the Shire of Gingin, Guilderton Caravan Park, Guilderton Visitor Centre, Tourism Western Australia and Country Values Holiday Homes, which manages some of the rental properties in Guilderton. This data was used to gain an understanding of the contribution of the Moore River Estuary to the local economy through tourism and provision of social values.

3.5 Limitations of the study

A limitation of this study is that the population was only surveyed on one weekend. Due to time constraints, it was not possible to survey the population at different times of the year. Ideally, surveying should be repeated over different time periods to identify any varying views. This is recommended to improve the generalisability of the results obtained in this study.

Secondly, the study did not look to capture the cultural value of the Moore River Estuary. Representatives of the Yued Noongar people were not interviewed due to time and resource constraints. Water resource

managers should consider the cultural value of the Moore River Estuary before making any groundwater management decisions.

4. Results

In this section, results from semi-structured interviews are presented first, followed by results from questionnaires.

4.1 Semi-structured interviews

A set of questions were used to guide the interviews and answer the research questions. These questions were grouped according to themes that emerged as the questions were being structured. The results from the interviews are addressed in the sections below under each theme.

i. Association of the interviewees with Moore River Estuary

Seven key stakeholders were interviewed in this study. They were homeowners or long-term residents of Guilderton or Caraban and people with a close and long-term association with the Moore River Estuary. One interviewee stated that he had been using the estuary for 70 years, from camping in the area as a child to later on visiting with his family for holidays. Another interviewee stated that he visited the estuary with his family every school holiday since 1962, up until 10 years ago, and stayed there all summer. The key learnings from the responses provided by these seven interviewees are summarised below.

ii. Values associated with the estuary

All the interviewees regarded the estuary as a unique and special place, describing it using words such as *`sheer beauty', 'relative isolation', `unspoilt and spectacular flora and fauna', 'there is no other estuary I know in such an undeveloped state', 'the kids' safety'* and *`a good family-friendly environment'.* They stated that the presence of water to maintain sufficient level and flow was required to maintain these values, as well as other factors such as control of the artificial opening of the sandbar, maintenance of fringing vegetation and cleanliness of the foreshore.

iii. Current condition of the estuary and changes observed over time

Six out of the seven interviewees were satisfied with the current condition of the estuary, stating that it had maintained its good condition despite increased use putting it under immense pressure. The other interviewee stated that he was not satisfied due to the silting of the river, mentioning that there was a jetty near the river mouth where people would dive into a `bottomless' pool and the area is currently too shallow and not safe to dive.

Although six interviewees were generally happy with the current state of the estuary, they mentioned that they had noticed the following changes over the time they had been using it:

- Estuary shallower due to infilling of sediment.
- More frequent algal blooms especially in summer, around Silver Creek and upstream of Woodridge boat ramp.
- Appearance of a 'prickly weed' in the estuary about 10 years ago.
- Rare occurrences of big fish.
- Less frequent natural opening of the sandbar, particularly during the dry season.

One interviewee mentioned that from 2010 onwards, the estuary was saltier as Gingin Brook flowed slower than in years past, resulting in less freshwater input while another stated that heavy rain from Gingin brought in darker tannins. Two interviewees stated that they had observed changes in the pattern of the opening and closing of the sandbar, as it previously opened earlier in April but now stayed closed

until July.

iv. Threats to the long-term health of the estuary

The interviewees stated that catchment practices, climate and both groundwater and surface water abstraction were all big threats to the long term health and condition of the estuary, as well as stock access to the river which could destroy riparian vegetation, artificial breaking of the bar and nitrates from the market gardens polluting the river and leading to algae proliferations.

Localised fresh groundwater contributions that maintain water level without breaching the bar was considered the most important factor contributing to the health of the estuary over the dry season by five interviewees. The other two interviewees thought that summer stream inflows and freshwater contribution from Gingin Brook that maintain water level without breaching the bar was the most important factor in maintaining estuarine health over the dry season.

Four interviewees stated the key to maintaining or improving the condition of the estuary during the dry season in the next 10-20 years would be education and control of the artificial opening of the sandbar, as this is crucial to maintaining the natural ecology of the Moore River Estuary. Other potential solutions raised by the interviewees were:

- Better understanding of groundwater seeps and inflows into the Moore River Estuary.
- Maintenance of localised groundwater connection in the estuary, especially in summer.
- Improved management of water use through smart irrigation techniques and reduction of water licenses where they are not needed.
- Restriction of development and management of human access into the estuary and the riparian zone.
- Revegetation and fencing to keep stock away from the river banks.

According to all the interviewees, low water levels affected swimming, fishing and boating, and this was only a problem when the sandbar at the river mouth was newly opened. They stated that this was a temporary problem as the estuary filled up quickly once the sandbar closed off again.

v. Changes in the social value of the estuary and potential threats to this value

All interviewees stated that there was an increase in visitor numbers to the estuary over the past few years, describing this using words such as *'huge', 'exponential growth' and 'sheer numbers of people'.* They stated that there were more people picnicking at the foreshore and more day-trippers and attributed this to the growing northern suburbs, better access through Indian Ocean Drive and the Gingin Shire beautifying the foreshore and making it more attractive to visitors. The interviewees also stated that the recreational use of the estuary had changed, with new activities such as waterslides at The Desert, paddle boarding and kayaking. Four interviewees said that deterioration in water quality or reduced groundwater and surface water inflows to the estuary would be a big threat to this growing social value. Increased development was thought to be a potential threat to the estuary's social value by two interviewees, with one of them describing the estuary as *'a place of restoration and an escape from the city'* and stating that over-commercialisation would destroy the social value of the estuary. One interviewee suggested that as the most used section of the estuary was the foreshore, maintenance of foreshore condition would be the key to maintaining the social value provided by the estuary.

According to five of the interviewees, deterioration in the condition of the Moore River Estuary would impact some activities but most people would continue to visit the estuary. The reason they gave for this was that some people would still visit for other activities such as bird watching and tourists who had not visited the estuary before would still visit and appreciate the river. Two interviewees however stated that

most people would not visit if there was a decline in the condition of the estuary as people visit the area to enjoy activities such as swimming, canoeing, sandboarding and fishing, all of which would not be pleasant to participate in if the estuary was in poor condition.

The interviewees all stated that maintaining the social value of the Moore River Estuary was critical to the local economy and businesses operating in Guilderton. They stated that businesses relied heavily on visitors especially during the peak season and that the Guilderton Caravan Park was fully booked from year to year.

4.2 Questionnaires

The questionnaires had questions relating to the respondents' use of the estuary, popular areas of use, factors that allowed for their use, changes observed over time and what would impact their enjoyment of the estuary. These questions were aimed at addressing the research questions. The results were grouped according to the general theme they addressed and are presented in the sections below.

i. Demographics

A total of 70 questionnaires were completed. Four respondents did not disclose their age. A deliberate attempt was made to capture the views of respondents across all age groups. Respondents between the age of 35 years and 65yrs had the highest representation (Figure 2).

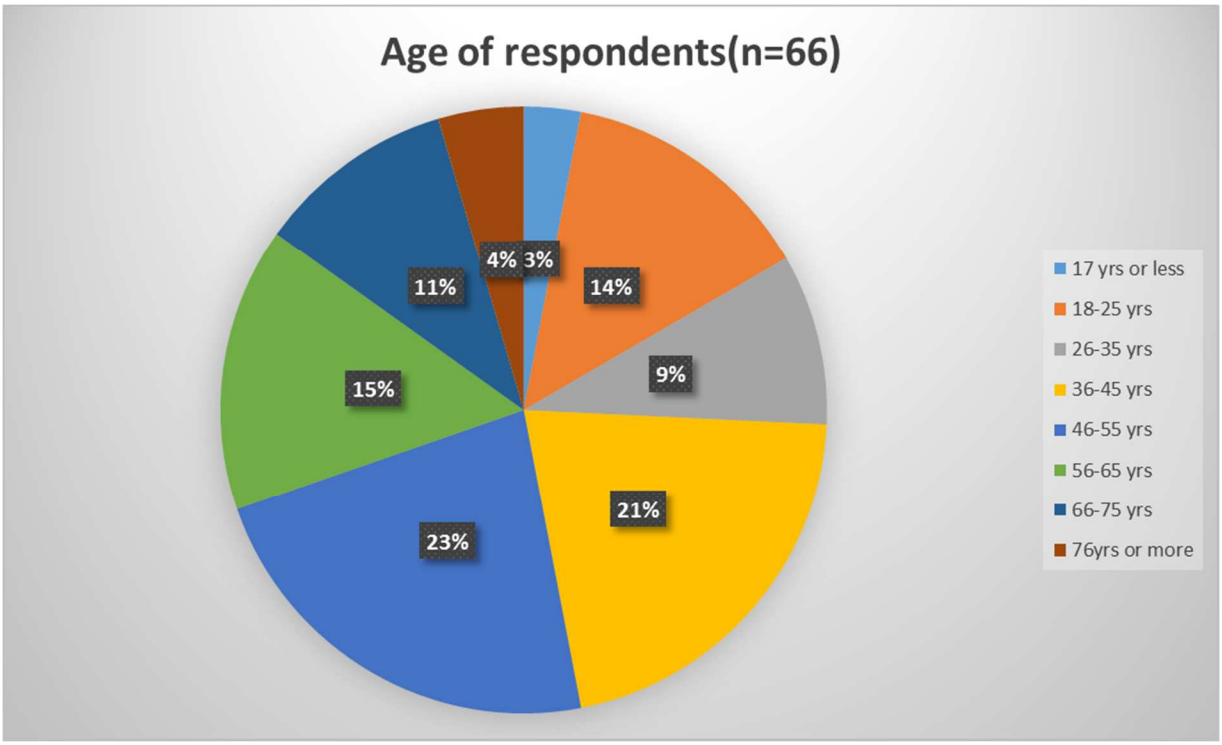

Figure 2: Age of respondents

Most respondents (36, 51%) were visitors, mainly from suburbs across Western Australia, while 21 (30%) were full-time residents of Guilderton and 13 (19%) were part-time residents, owning holiday homes in the area.

ii. How often do people visit the Moore River Estuary?

Most respondents (53, 78%) stated that they visited the Moore River Estuary every year while 30 (43%) stated that they had been visiting the estuary over a period of time greater than 10 years. Only 8 (11%) respondents were first time visitors.

Spring/summer was a popular time to visit, with 32 (54%) respondents stating that they visited at this time when the weather was warm as well as during school holidays. The rest of the respondents (27, 46%) stated that they did not always visit at the same time of the year.

iii. Why is the Moore River Estuary valued by those who use it?

The beautiful scenery at the Moore River Estuary is highly valued by those using it, with most respondents (55, 79%) stating this as the reason why the Moore River Estuary was important to them. The quiet and peaceful environment as well as recreational activities undertaken at the estuary were also valued by most respondents (50, 71% each). Other reasons why the estuary was valued by its users were: safe area for recreation (48, 69%), getaway close to Perth (48, 69%), unique environment and wildlife (45, 64%), cultural significance (9, 13%) and good location for business (6, 9%).

The most popular recreational activities at the Moore River Estuary, as shown in figure 3 below, were swimming and kayaking/canoeing. Fishing and viewing scenery were equally popular among the respondents while other activities mentioned by respondents that were not captured in the questionnaire included photography, peaceful relaxation and picnics.

Generally, the respondents' enjoyment of the estuary was not affected by the sandbar being open (60, 86%). However, a few respondents (7, 10%) stated that their enjoyment of the estuary was affected by the sandbar being open, citing low water levels affecting boating, water quality, swimming at Silver Creek and safety reasons. Two of these respondents stated that it was dangerous to swim or kayak near the mouth when the sandbar opened and one respondent stated that she enjoyed kayaking out into the ocean when the sandbar was open. Three respondents (4%) did not know whether their enjoyment of the estuary was affected by the sandbar being open.

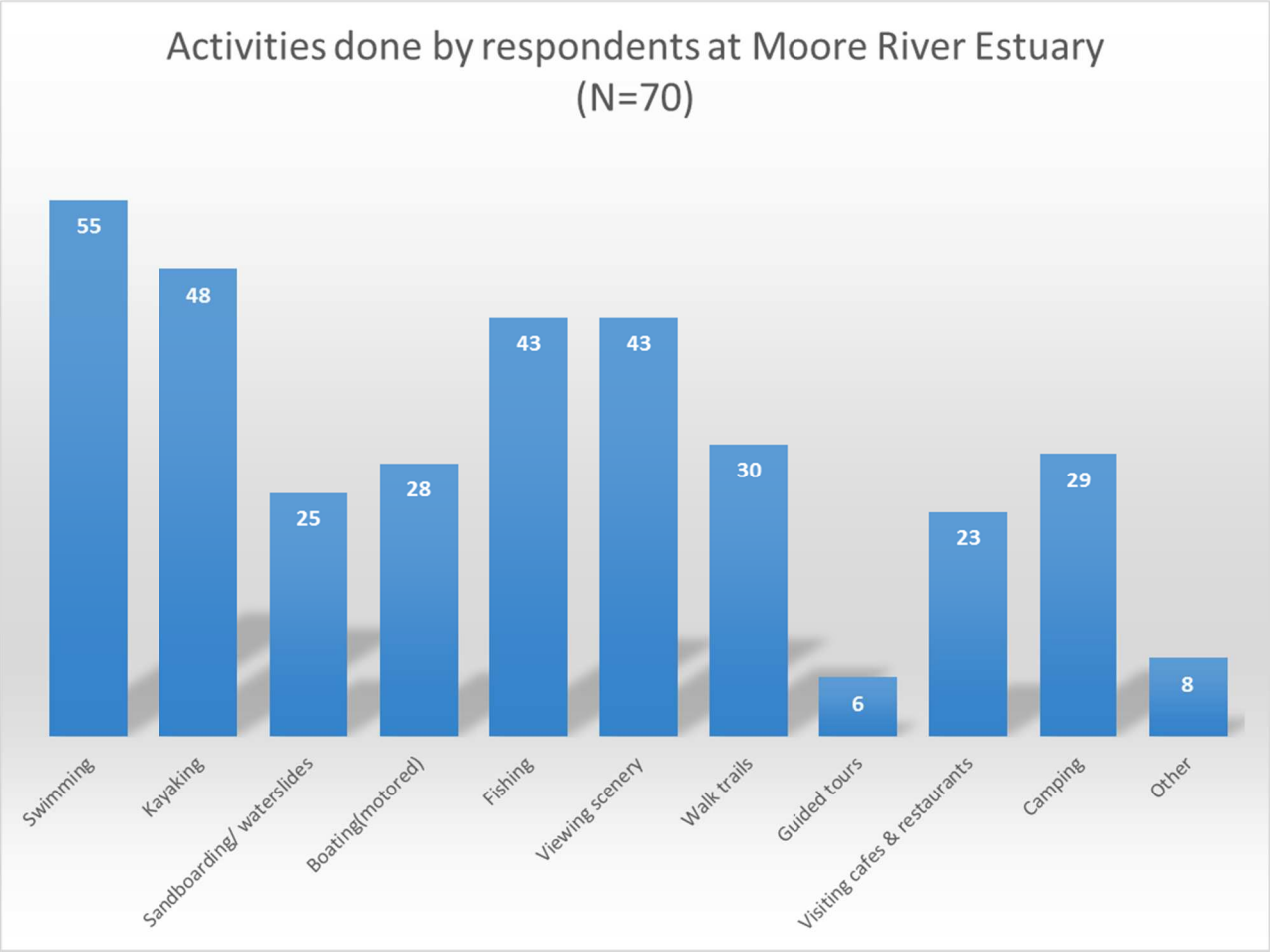

Figure 3: Activities done at the Moore River Estuary

iv. What are the most popular areas of use at the Moore River Estuary?

The most used areas of the estuary are the foreshore (44, 66%), `The Desert' (31, 46%) and the extent of the estuary mostly used for boating, kayaking, canoeing or paddle boarding (31, 46%). Other areas of use were walk trails/fishing spots (27, 40%), Silver Creek (26, 39%), Caraban boat launch (22, 33%) and the free overnight camping grounds above Indian Ocean Drive (6, 9%).

v. How important are the following factors for the enjoyment of the Moore River Estuary? (Appearance of water [colour, smell, absence of algae], water quality for human recreation, overall water level/depth at location of use, riverbank vegetation, presence of fish)

Over half the respondents said that the water in the estuary had good appearance, water level and depth; supported nice riverbank vegetation and fish; and its quality was suitable for human recreation, and the combination of these factors allowed them to use the estuary the way they did. Others stated additional factors such as absence of predators and the safety of the estuary as it is shallow and sheltered from strong winds and waves.

Water quality was clearly the most important factor in supporting the respondents' enjoyment of the estuary, with 32 (47%) rating it as absolutely essential and 27 (40%) stating that it was very important. The appearance of water, riverbank vegetation and presence of fish were also considered significant for respondents' enjoyment of the estuary (Figure 4). Water level and depth had a more even spread of responses with 12 (18%) of the respondents believing it did not impact their enjoyment of the estuary.

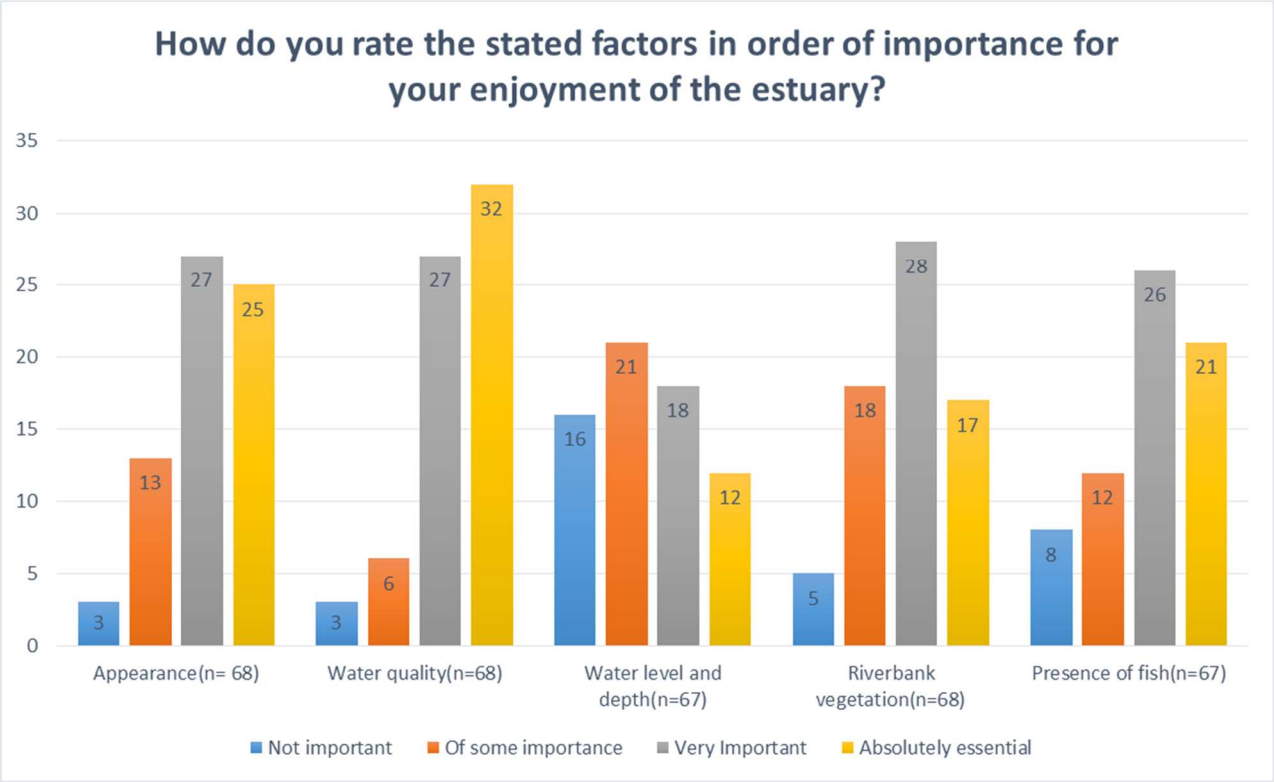

Figure 4: Respondents' ratings for importance of factors for their enjoyment of the estuary

vi. Have there been any changes in the appearance, water quality, water level and depth, riverbank vegetation, presence of fish and natural timing of the opening/closing of the sandbar in the Moore River Estuary over time?

Most of the respondents stated that they were satisfied with the current state of all the factors presented. Those who were not satisfied stated the following reasons: darker colour of the water, shallow water in some areas, destroyed vegetation, presence of rubbish and reduced fish stocks over the years.

More than half of the respondents (34, 56%) stated that they had not noticed any change in the condition of the estuary over the time they had been visiting while 23 (38%) stated they had noticed a difference. Those who said that they had noticed a change in the condition of the estuary listed the following changes: improved riverbank vegetation, changes in timing of the opening and closing of the sandbar, lower water levels than before, darker water colour and silting of the estuary. Some respondents stated that there were frequent algal blooms, especially in the summer months since 2010. However, one respondent mentioned that algal blooms were less than in the mid-1990s. Only five (8%) of the respondents stated that they were happier with the condition of the estuary in the past stating that there was less algae, less tannins, less rubbish and less development.

According to 30 (53%) respondents, there was a change in the number of people visiting the estuary. Most of these respondents (20, 67%) stated that they had observed an increase in visitor numbers while six (20%) stated that they had observed a decrease in numbers.

vii. What would stop people from visiting or enjoying the estuary?

Anything that would negatively impact the appearance and smell of the water and its quality would be the greatest hindrance to respondents' enjoyment of the estuary (Figure 5). Respondents also mentioned general loss of present ambience, unregulated use of personal watercraft, real estate development, too many people, litter and pollution as other reasons that would stop them from visiting or enjoying the estuary.

Some respondents (15, 22%) stated that the condition of the estuary did not impact their willingness to visit or enjoyment of the estuary (Figure 5). More than half the people surveyed said they would not return to the estuary as a visitor or enjoy it if they were a local, if any of the following changes occurred:

- Impact to the appearance and smell of the water body (46, 68%)
- Water quality no longer being safe for human recreation (43, 63%)
- Impact to fish health and loss of fish species (35, 51%)

The survey showed that if water level became too low to undertake an activity they enjoy, just under half of the respondents (30, 44%) would no longer continue to visit or enjoy the estuary. Loss of riverbank vegetation or a deterioration in its appearance would impact willingness to visit or enjoyment of the estuary in other respondents (28, 41%).

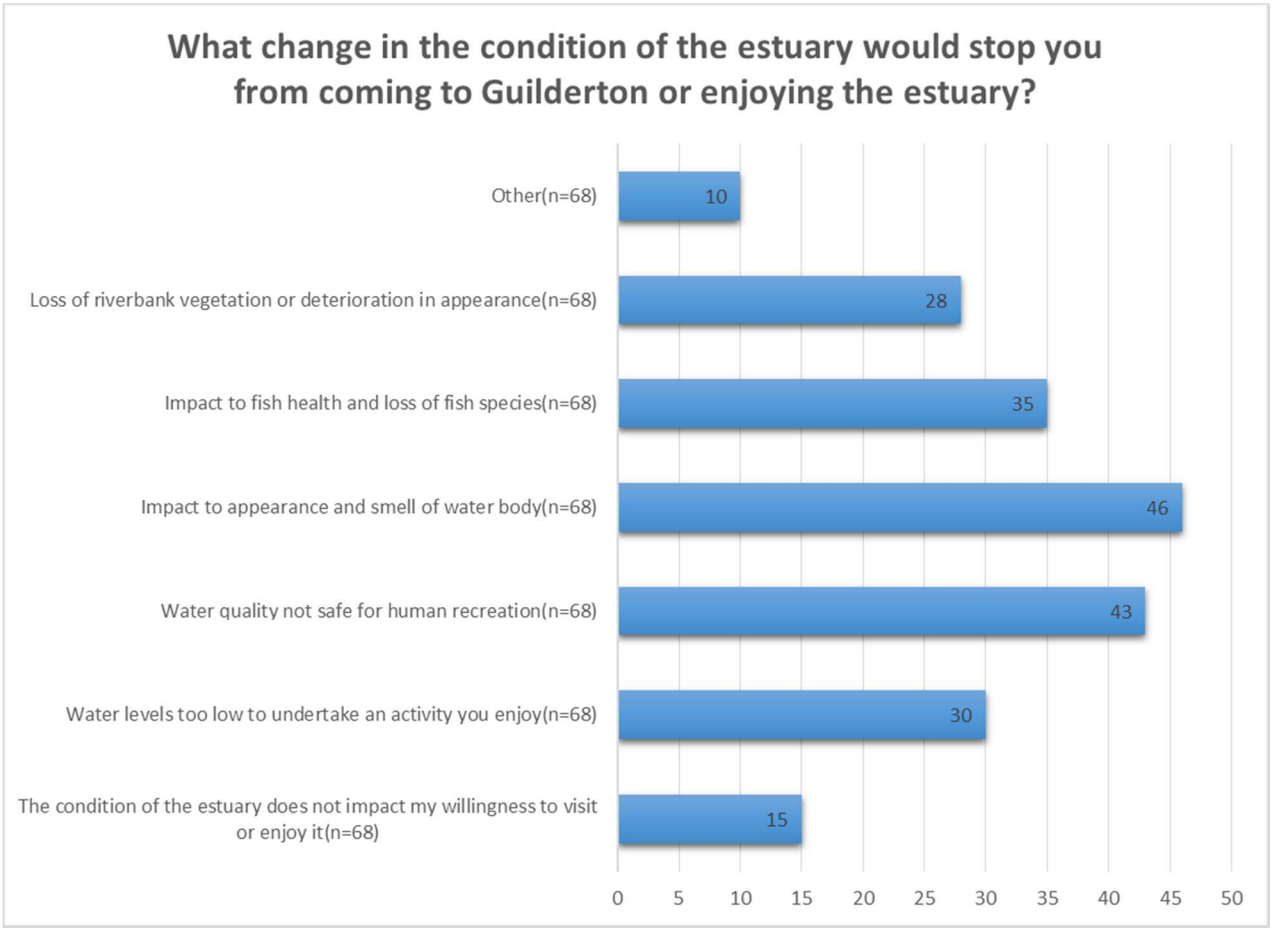

Figure 5: What change in the condition of the estuary would stop people from visiting or enjoying the estuary?

5. Discussion

In this section, the research questions are answered by discussing the results from the surveys, interviews and collated tourism data, and comparing these results with findings from reviewed literature.

5.1 What are the social, environmental and economic values provided by the Moore River Estuary and how have they changed over time?

In this section, the social, environmental and economic values of the Moore River Estuary, as obtained from surveys, interviews and collated tourism data, are discussed individually and compared with findings

from reviewed literature.

Social Value

The results of the interviews and survey responses in this study show that the Moore River Estuary provides an important social value to visitors and the local community. It provides an opportunity for recreation, interaction among families and friends, relaxation and a chance to get away from daily life. As seen in the survey, most respondents visited the estuary to participate in recreational activities such as swimming, kayaking and fishing while some simply enjoyed the serene environment and the aesthetic appeal of the estuary. When asked why the Moore River Estuary was important to her, one of the surveyed respondents said *`it soothes my soul'*. Such pristine environments enhance human health and mental well-being. A study by McManus, Hunt, Storey and White (2011) highlights the physical and mental health benefits of recreational fishing and access to waterways for recreation. The value of such ecosystem services cannot be ignored, and should be considered in the management of water resources.

Most of the survey respondents and interviewees in this study have a strong sense of attachment to the Moore River Estuary and have made the estuary their summer holiday destination year after year. This social value should be maintained. Although it can be difficult to quantify social values, they need to be considered in water planning as they offer vast benefits to the community, and influence the community's reactions to water management decisions (Taylor, Hamstead & Prior, 2012).

The recreational use of the Moore River Estuary has changed over the years, with most interviewees and respondents stating that different recreational activities such as stand up paddle boarding and waterslides at 'The Desert' are gaining popularity at the Moore River Estuary. The interviewees in this study stated that they opposed the use of jet skis on the river due to erosion impacts to the river banks and noise nuisance. They also highlighted boats travelling above the speed limit of five knots as a concern for the safety of those swimming and kayaking in the estuary, and river bank erosion.

According to most interviewees and survey respondents, there has been an exponential increase in visitor numbers, particularly over the last five to 10 years, and this was thought to be due to better access through the development of Indian Ocean Drive, expansion of Perth's northern suburbs and the Gingin Shire beautifying the foreshore. This is consistent with the predictions by Black (2001) stating that the popularity of the Moore River Estuary would increase with the expansion of the metropolitan area towards the north. There has been an increase in day- trippers as predicted by Black (1999) and the Shire of Gingin has had to provide additional facilities such as toilets and bins to cope with the increase in visitor numbers. This led to the introduction of parking fees in 2018 to help finance these facilities.

Most interviewees stated that there has been increased use of the foreshore for picnics. The type of visitors to the Moore River Estuary has shifted from mostly Australians to a more multicultural representation. Through speaking to respondents at the foreshore, it became apparent that most of them were not confident swimmers and preferred to enjoy the view from the foreshore and wet their feet in the shallow waters of the estuary. Most people visit the estuary on weekends and during holidays, and the foreshore gets overcrowded. This was observed on the long weekend commencing on the 21st of September 2018 when surveying was conducted, which coincided with the start of third term school holidays (figure 6).

Figure 6: The crowded foreshore during the long weekend when surveying was done

Environmental value

The Moore River Estuary is a pristine ecosystem with a range of environmental values, as was observed in the interviews and surveys in this study. This value was appreciated by the interviewees and survey respondents in this study, with many of them enjoying fishing for native black bream and viewing of the scenery and the variety of bird species the estuary attracts. Aside from the popular black bream, other native aquatic species sampled within the study site include western pygmy perch (*Nannoperca vittata*), southwest goby (*Afurcagobius suppositus*), nightfish (*Bostockia porosa*), cobbler (*Tandanus bostocki*) and gilgie (*Cherax quinquecarinatus*) (Storer et al. 2011a, b).

The estuary's remnant vegetation provides habitat to native bird species and wildlife such as the endangered Carnaby's Black Cockatoo and kangaroos (Guilderton Visitor Centre, n.d.). The estuary provides an ecological corridor for these species, connecting different sections of vegetation across the landscape. Tuart trees (*Eucalyptus gomphocephala*) as well as swamp paperbark (*Melaleuca rhaphiophylla*) are just some of the native flora that can be found along the banks of the Moore River Estuary (Figure 7). Apart from providing habitat to birds and wildlife, the presence of vegetation along the estuary also protects the banks from erosion as the roots hold together soil particles and the branches and leaves act as a wind break.

One interviewee stated that the *'unspoilt, spectacular flora and fauna'* made the estuary a unique and special place. However, some interviewees complained of the reduction in size and number of fish over the years. One interviewee believed that this was due to the silting and infilling of the river over time which has resulted in the loss of fish habitat. More than half of the respondents surveyed stated that they would not continue to visit or enjoy the estuary if there was a loss of fish species or an impact to fish health. In most cases, this was not related to an impact to recreational fishing, but rather because the respondents believed that the presence of healthy fish in the estuary signified that the ecosystem was healthy, and this was critical for their enjoyment of the estuary.

The interviewees were all very aware of the environmental value of the Moore River Estuary and

acknowledged the efforts of the Lower Moore River Working Group in contributing to the improved condition of the estuary since 2010. The community group has worked with landholders along the Moore River, erecting fences to prevent stock access to the river and revegetating degraded areas. This has stabilised the river banks and prevented further erosion. Two interviewees stated that these activities had improved the condition of the estuary over the last five to 10 years. Such efforts by community groups should be encouraged.

During interviewing, two interviewees mentioned that they had observed species of Melaleuca around Silver Creek dying between 1999 and 2009. The cause of this was not known but the interviewees thought that this was related to a salinity event in the estuary. They stated that the trees had recovered since then. Although the cause of this deterioration is unknown, Silver Creek is fed by groundwater (Siemon, 2000) and extreme salinity events or reduced groundwater levels could have affected the trees. A similar event of stress on fringing vegetation is recorded in a study by Grimes and Eliot (1998) stating that between 1995 and 1998, Tuart trees along the Moore River Estuary died. According to Grimes and Eliot (1998), this corresponded with a period of low groundwater levels, and this could have caused the death of the trees. Due to a lack of groundwater monitoring in Silver Creek and the surrounding catchment of the study area, it is not possible to prove this theory.

Figure 7: Flora and fauna at the Moore River Estuary

Flora and fauna will continue to respond differently to the drying climate and rising temperatures. This uncertainty brought by climate change therefore requires strategic decision-making regarding changes in the allocation of water, both for the environment and the society (Horne et al., 2017). Water resource managers need to understand the environmental value of the Moore River Estuary and the importance of groundwater in supporting this value, in order to make sustainable water planning decisions in the areas around the estuary.

Economic value

There are only a few operational businesses at the Moore River Estuary: Guilderton Country Club, Moore

River Roadhouse (known to residents as 'Top shop'), Guilderton General Store or 'Bottom shop', Guilderton Caravan Park, Moore River Cruises, and canoe, kayak and stand up paddle board hire businesses. There are many rental properties in Guilderton which are a source of income to home owners and companies such as Country Values Holiday Homes (CVHH) who currently manage 22 properties in Guilderton (Pers. Comm., CVHH).

All interviewees in this study stated that these businesses were dependent on increased visitor numbers during peak periods to earn the most of their income. Anything that causes a decrease in visitor numbers to this region would affect the viability of these businesses, and according to the interviewees, most would cease operation.

The results of the questionnaires showed that some respondents took part in activities that generated income for local businesses. These were activities such as camping, visiting cafes and restaurants, guided tours, and hiring of canoes and kayaks.

Estimates of visitor numbers to the Moore River Estuary were obtained from Tourism Western Australia, Shire of Gingin, Guilderton Caravan Park, CVHH and Guilderton Visitor Centre. Information provided by the Shire of Gingin showed that since the parking meters were installed on the 30th of April, 2018, until the 11th of October, 2018, a total of 4,628 parking tickets had been issued. Although there is no way of telling the number of people per car, this figure predicts a large number of visitors within a period of six months, considering that these statistics only capture the low season at the Moore River Estuary and some visitors park at the free car park located at the lookout. Residents of the Shire of Gingin and visitors renting property at the Moore River Estuary are provided with parking permits.

Supporting the observations of interviewees and the responses from questionnaires stating that there had been an increase in visitor numbers to the Moore River Estuary, the Guilderton Caravan Park Manager stated that the caravan park had experienced a 10% growth in visitor numbers since he took over six years ago and generates an annual revenue of $1.5 million (Pers. Comm., Geoffry Liddelow – Caravan Park Manager). Records from the Guilderton Caravan Park show that tourists from all over the world visit the park, with the highest number of visitors being from Western Australia (Table 4).

Table 4: Guest statistics from Guilderton Caravan Park for the 2017/18 financial year

Place of Origin	Number of Guests
Western Australia	15,626
Australia(other)	3,444
Europe	684
Asia	80
America and Canada	42
New Zealand	33
Africa	8
Other islands in Oceania	5
Unknown	4

For visitors who rent holiday homes in Guilderton, the average length of stay is three nights during peak season (December to March). Data received from CVHH shows that Guilderton had the highest number of nights booked, in both 2015/16 and 2016/17 financial years, compared to other neighbouring holiday towns (Figure 8). This highlights the popularity of the Moore River Estuary as a tourist destination.

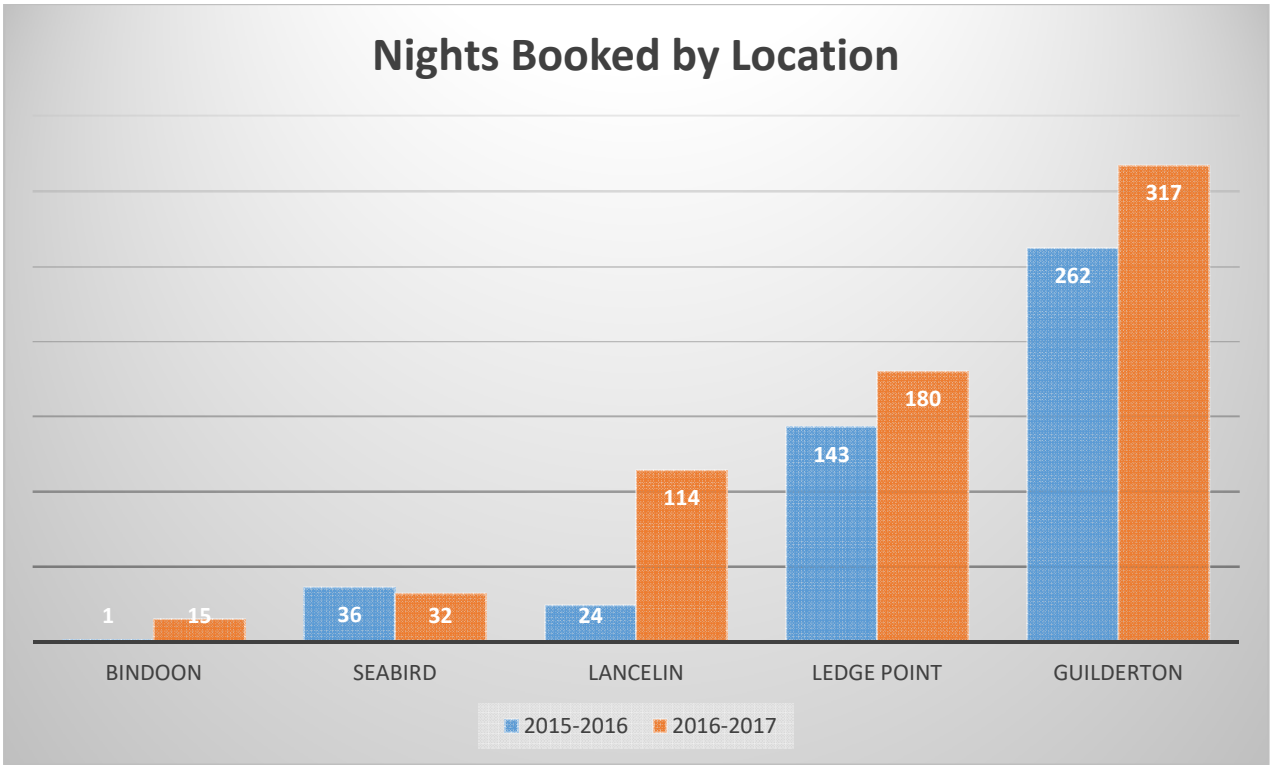

Figure 8: Nights booked in Guilderton and other popular holiday towns (Source: CVHH)

Data from CVHH shows that as of October 2018, there were 30 private rentals and 77 rentals under management by providers such as CVHH, Airbnb and Stayz (Pers. Comm., CVHH). The gross rental income to homeowners under management by CVHH is shown in Table 5 below.

Table 5: Gross rental income to homeowners under CVHH (Source: CVHH)

Financial year	Income	Number of properties listed
2014-2015	$270,000	18
2015-2016	$230,000	17
2016-2017	$320,000	24

5.2 How important is the condition of the Moore River Estuary to maintaining its social and economic value?

The pristine condition of the Moore River Estuary plays a significant role in providing for its social and economic value (Black, 1999). According to most of the interviewees in this study, it was mainly the presence of the Moore River that brought people to Guilderton, and one interviewee stated that *'if it wasn't for the river, there wouldn't be anyone here.'* Through their responses, the surveyed respondents consistently highlighted their appreciation of the condition of the estuary, stating that its appearance and water quality were critical factors for their continued use. The surveyed respondents in this study stated that the top four reasons that would stop them from visiting Guilderton or enjoying the estuary, as shown in Figure 5, were:

- Impact to the appearance and smell of the water body
- Poor water quality (not safe for human recreation)
- Impact to fish health and loss of fish species
- Water levels being too low to undertake a recreational activity

Based on the results of the survey, any negative impact to the appearance, water quality, fish health and water level in the estuary will have a significant effect on visitor numbers and the economic value of estuary. Businesses in Guilderton and areas surrounding estuary will be affected, as they rely heavily on visitors to the region, especially during the peak season, to be economically viable. As observed in the surveys in this study, fishing, swimming, kayaking/canoeing and viewing scenery were all very popular activities in the estuary, which rely on the factors presented above. These results are consistent with those presented by Black (1999), stating that fishing, swimming and viewing scenery were the most popular activities at the Moore River Estuary and anything that negatively impacted the natural environment or water quality would affect the popularity of the area.

All the interviewees in this study stated that fishing, swimming and boating in the estuary were all impacted by low water levels at different times of the year. This mostly happened when the sandbar was artificially broken, and water levels in the estuary dropped drastically. They however pointed out that this was not a major problem as when wave action started to build up the sandbar again, the estuary filled up quickly, even in summer when streamflow from Moore River and Gingin Brook was minimal. The response in water level is due to groundwater discharge to the estuary, which can be seen as seeps along the river banks at low water levels. As the climate continues to dry, maintenance of groundwater connection to the estuary will be critical to providing the water levels needed to support its social values.

When low water levels persist, especially in warm weather, algal blooms can occur in the estuary. Toxic species of algae can severely impact water quality, restricting recreational activities such as swimming. Non-toxic species can also be a nuisance and reduce the estuary's aesthetic appeal. One interviewee stated that he no longer visited the area of the estuary upstream of Caraban boat launch as algae in this area stalled the motor on his boat about 10 years ago. According to Cousins and Tracey (2003), the algae that has been previously found at the Moore River Estuary is not harmful, but changes in future environmental conditions could lead to an increase in algae or introduction of toxic species. This will reduce the social value of the estuary by impacting most recreational activities, and likely decreasing the popularity and economic value of the estuary. Groundwater management in the estuary should focus on maintaining the appearance, water level and water quality in the estuary to maintain its social and economic values, and meet the expectations of the local community and visitors.

5.3 What is the desired future state of the Moore River Estuary to the local community and visitors?

The local community and visitors are generally happy with the current condition of the Moore River Estuary. Six of the interviewees in this study, who had closely observed the estuary over many decades, stated that they were happy with its current state. They also stated that they did not want any deterioration from the current condition. The interviewees identified catchment practices, climate and water abstraction as equal threats to the long term health and condition of the estuary. One interviewee mentioned that expansion of horticulture and agriculture in the area has increased water demand far beyond what is sustainable for the environment and the Moore River system. Another interviewee stated that according to his observations, the water table in the area had dropped by about six meters in the last 20 years, possibly due to increased groundwater abstraction.

A study by Strategen and UWA (2005) highlighted that the community at the lower Moore River perceived that there was a decline in summer base flows in the river. Although they did not verify this, possible reasons for the decline were stated as climate change, surface water abstraction and groundwater abstraction. The interviewees in this study had similar concerns. Due to the lack of hydrogeological understanding around the estuary, it is not possible to clearly identify the effect that abstraction has had on both surface and groundwater flows into the estuary. An improved understanding of the estuary's

hydrogeology and groundwater-surface water interaction is necessary to inform future decisions around groundwater abstraction in surrounding agricultural areas.

Very few survey respondents stated that they had observed changes in the condition of the estuary over the time they had been using it. Of these respondents, some raised concerns about the silting of the river. One respondent stated that this was due to sand-sliding at 'The Desert'. However, it is difficult to quantify the amount of silt brought into the estuary by sand-sliding alone. In a study of the sediments of the estuary, Wilson and Eliot (2000) recommended that 'The Desert' should be rehabilitated and stabilised to reduce the amount of sand it feeds into the estuary. Bathymetry studies have been previously conducted on the estuary by the Department of Transport between 1998 and 2002 (Cousins, 2003) and new studies would be useful in identifying whether the estuary is infilling with sediment, as mentioned by some survey respondents and interviewees in this study.

Cousins (2002) states that frequent opening of the bar reduces flushing of sediments from the estuary and this could also be contributing to the silting of the river. Allowing water level in the estuary to build up and break the sandbar naturally will encourage flushing of the estuary. Although most of the surveyed respondents stated that their enjoyment of the estuary was not affected by the sandbar being open, the interviewees, who had an intimate knowledge of the estuary, all thought controlling the artificial opening of the sandbar was critical to maintaining the current healthy condition of the estuary.

The sandbar is a significant feature of the Moore River Estuary, providing a safe area for recreation when closed. It provides good sand banks into the ocean for surfers open, which is the main reason why the sandbar is artificially opened (Water and Rivers Commission, 2000). The artificial opening of the sandbar has been an issue of concern since the 1930s (Grimes & Eliot, 1998) and continues to be a problem. The sandbar is important for regulation of water quality and water level in the estuary (Anderson, 2004). When open, the water level in the estuary drastically drops and the dark tannin colour of water in the river is reduced, possibly due to groundwater discharge (Anderson, 2004). Light penetration into the water column is improved, providing a suitable environment for algal growth. Frequent artificial opening of the sandbar should be discouraged as it has an adverse effect on the estuarine ecosystem and can lead to water quality problems in the estuary.

As the climate in south-west Western Australia continues to dry (DoW, 2015b), the water level in the Moore River Estuary is likely to drop and this will affect water quality. The effect of nutrients is likely to be more significant when water level is low and this might lead to an increase in visible algae (Cousins, 2002), affecting the aesthetic value of the estuary as well as recreational activities. Maintenance of groundwater levels and connection with the estuary will be critical for the maintenance of its current state.

6. Conclusion

The overall aim of this study was to identify the value of the Moore River Estuary to the local community and visitors, and the condition that needs to be maintained to continue to provide this value. From the results of this study, it is apparent that the Moore River Estuary continues to provide an important social, economic and environmental value to its users. The key stakeholders, local community and visitors captured in this study were overall satisfied with the estuary's current condition. This condition should be maintained to meet community and visitor expectations, and preserve the social, environmental and economic values it provides.

From the survey, it is clear that the maintenance of the current healthy condition of the estuary and the values it provides is reliant on three main factors.

1. Maintenance of the current appearance and smell of the water body

2. Maintenance of water quality suitable for human recreation
3. Continued presence of healthy fish populations

The study also highlighted that to achieve this future healthy condition under a drying climate, maintaining the local groundwater connection with the estuary will be essential. Since 2010, Gingin Brook and Moore River began to cease flowing into the estuary in some years during summer. Summer freshwater inflows from Gingin Brook in particular were thought to be a major reason for the estuary being healthy and maintaining good water quality and water level over summer. Stakeholder input and literature reviewed in this study has identified that even in summers of no stream inflow, water quality in the estuary is being maintained at suitable levels for human recreation, and water levels are recovering quickly following the artificially opening of the sandbar. Without this strong groundwater interaction, water levels in the estuary would take longer to recover from events such as this and likely lead to water quality issues, disconnected bodies of water and associated impacts to the social values identified.

Future groundwater management in the Gingin and Gnangara groundwater allocation plan areas should focus on maintaining localised groundwater connection with the estuary, to ensure its appearance and smell, water quality and presence of healthy fish populations are maintained. This will become increasingly important in the future as the climate continues to dry and stream inflows from Gingin Brook and Moore River reduce.

7. Recommendations for future work

The findings from this research reveal knowledge gaps and management actions that will assist in the management of the Moore River Estuary. The following recommendations have therefore been made.

Recommendations to DWER

- **Further research to build on this study**

Due to time constraints, it was only possible to survey the population under study on one weekend. Whilst this weekend was the start of the peak season at the estuary and a wide array of views were captured, additional studies surveying a similar population of recreational users of the estuary, at different times of the year, is recommended to determine if differing views exist.

It was also not possible to capture the views of the Yued Noongar people due to time and funding constraints. It would be useful to conduct an interview with representatives from the Yued people as the Moore River Estuary is an area of cultural significance for this community. Their views should be captured to inform future management of groundwater use around the estuary.

- **Hydrogeological investigations should be conducted to provide a better understanding of groundwater-surface water interaction along the Moore River Estuary**

During this study, it became apparent that there was a knowledge gap regarding the hydrogeology of the Moore River Estuary. From speaking to DWER hydrogeologists, it was apparent that there is a lack of monitoring data to inform groundwater interaction along the estuary. This information is available further upstream for Gingin Brook, and will be needed to inform the management of groundwater use around the estuary as climate dries.

Although most interviewees believed that the estuary relied heavily on groundwater connection, they said that these were assumptions and there were no studies that had ascertained this. Hydrogeological studies to inform the groundwater-surface water interaction along the estuary will be important to inform future water allocation decisions in areas around the estuary within the Gingin and Gnangara groundwater

allocation plan areas.

Recommendations to Gingin Shire, local community and catchment management groups

- **Education on the sandbar**

Frequent artificial opening of the sandbar should be discouraged through education of visitors and local residents. Signs are currently present at the foreshore to educate visitors on the effects of artificial opening of the sandbar but improvements could be made in their location and design to make them more conspicuous and effective in changing behaviour.

The language used should be educational rather than authoritative, designed to connect with youth and surfers most likely to dig out the sandbar. Signage should be placed strategically at locations where they are obvious to those accessing the river mouth, such as at the jetties, along the foreshore and key access points to the river mouth such as stairs and paths.

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Appendix A: Daily Work Schedule

Title	Description	Date/ Time
Project preparation	Thorough review of literature to familiarise with the subject of study as well as the study area.	Mostly in August but continued throughout the project as I familiarised myself with qualitative research techniques.
Ethics approval	Prepared all the required documentation for an ECU ethics approval as the project involved interviews and surveys. I was later informed that ECU would not provide an ethics approval for this project as it was not a student or staff project, and ideally was under ownership of DWER	14th August-5th September
Meetings (General)	Meeting with section manager to discuss how the Environmental Water Planning Section works and how my project fits into their work.	31st July
	Meeting with Branch manager- I had two meetings with my workplace supervisor and the Branch manager. The first was to discuss project scoping and the second was to discuss our approach to surveying at the Moore River Estuary.	Two meetings, on 1st August and 12th September
	Meeting with Director General to brief him on our projects	27th August
	Branch meeting	7th August
	Section meeting	7th August
Meetings (Workplace Supervisor)	I interacted with my supervisor on a daily basis and briefed him on my daily progress. We often had meetings on Monday mornings to set tasks for the week ahead and on Friday afternoons to discuss progress made.	Throughout the project
Meetings (ECU Supervisor)	I regularly emailed my ECU	Throughout the project

	Supervisor and consulted with him every week. We had three meetings, one at DWER and two at ECU Joondalup	Meetings: ECU Joondalup-2nd August, 2nd October DWER offices-22nd August
Meetings (Project support)	Meeting with the water science team at DWER to discuss some studies they had done at Moore River Estuary	7th August
	Meeting with hydrologists at DWER to discuss groundwater dependency of the estuary	8th August
	Meetings with stakeholders to discuss the project and their association with the estuary	31st August, 11th September
Operational activities	I learnt how to book meetings with my colleagues at work as well as how to book a work car for field trips.	Throughout the project
Field work	A reconnaissance trip to the Moore River Estuary. This trip enabled me to familiarise with my project study area as well as meet two key stakeholders whom I interviewed later on. During this trip, I also got to conduct water sampling. This was very exciting as I had learnt the theory behind these procedures in the previous semester in a unit titled Environmental Monitoring and Investigation.	17th August
Stakeholder engagement	I gained a lot of skills and knowledge on stakeholder engagement through this project. My workplace supervisor and I met all the key stakeholders that we wanted to interview and informed them about their project. We asked if they had any additional information on the project or any suggestions of people who could provide useful information.	This was done through phone calls, emails and meetings throughout the project.
Pilot tests	Pilot testing of questionnaire and interview questions	29th August, 13th September, 14th September, 20th September

Data collection	Surveys and interviews	17th- 26th September
Data analysis	Done through hand coding and excel	27th September-5th October
Presentation	Prepared project presentations for ECU and DWER.	ECU-26th September DWER- 30th October
Report writing	Summary of project findings for ECU and DWER report	8th October- 9th November

Appendix B: Survey Instrument (Interview questions)

Consideration of the value of estuarine environments in groundwater management: Case study Moore River Estuary

Project Aim: To clearly identify the value of the Moore River Estuary to the local community and visitors, and the condition that needs to be maintained to continue to provide this value.

INTERVIEW QUESTIONS – KEY STAKEHOLDERS

1. Your name/organisation
2. What is your association with the Moore River Estuary?
3. For how many years have you visited or used the estuary?
    a. Frequency/time of year/length of stay
4. In your opinion what makes the estuary such a unique and special place?
    a. What is needed to provide this value to you?
5. Are you satisfied with the current condition of the estuary?
    a. If yes, why?
    b. If no, was there a time in the past when you were more satisfied? Why?
6. Have you noticed any changes to the condition of the estuary over time? Describe these changes with reference to the considerations below.
    a. When did these changes occur?
    b. Were they a trend over time or a point in time?
    c. Did they relate to changes in rainfall, streamflow, groundwater seepage or temperature?
    d. Something else? E.g. catchment practices, water abstraction/allocation
7. Did you notice any particular changes to the estuary from 2010 onwards?
    a. Consider appearance, water levels, water quality, flow, groundwater seeps, and riverbank vegetation condition.
8. Of options a – d below, which do you think are the most important in contributing to a healthy estuary over the dry season and why? Anything else?
    a. Strong winter flows that flush out the estuary before the sandbar closes in summer
    b. Summer stream inflows from Moore River that maintain water level without breaching the bar
    c. Summer stream inflows and freshwater contribution from Gingin Brook that maintain water level without breaching the bar
    d. Localised fresh groundwater contributions that maintain water level without breaching the bar
9. What do you think is the biggest threat to the long term health and condition of estuary? Consider the options below and explain your answer:
    a. Catchment practices
    b. Climate
    c. Water abstraction (groundwater or surface water?)
    d. Other
10. What do you think will be the key to maintaining or improving the condition of the estuary during the dry season in the next 10-20 years? Explain.
11. What areas of the estuary and activities are you aware of that are impacted by water level at certain times of the year?
    a. Are low water levels ever an issue when the bar is closed?

    b. Consider depth needed for fishing/boating, to allows canoers access to upstream areas, swimming/diving/sand dune /water slide ramps/launchers.
12. Have you observed any changes to the recreational use of the estuary, tourism or visitor numbers over time?
    a. If yes, why do you think this was?
    b. Did it have anything to do with the condition of the estuary?
13. What do you think is the biggest threat to the social value the estuary provides?
    a. Consider what will impact people's willingness to use or visit the estuary the most
14. How do you think a deterioration in the condition of the Moore River Estuary (think appearance, water level, estuarine health) will impact its social value and consequently visitor numbers to the area? Which areas (refer to map)? Select from the options below and explain your choice.
    a. People will continue to visit the area and use the estuary regardless of its condition
    b. Some activities will be impacted by a decline in condition but most people will continue to visit and use the estuary
    c. Most people will not continue to visit and use the estuary if there is a decline in condition
15. How important do you think maintaining the social value of the Moore River Estuary is to the local economy and businesses operating in Guilderton? Select from below options and explain your selection.
    a. Change to the social value of estuary will not impact the local economy
    b. Change to the social value of estuary will have a slight impact on the local economy
    c. Change to the social value of estuary a moderate impact on the local economy
    d. Maintaining the social value of the estuary is critical to the local economy
16. Who else do you think could provide valuable input to these questions through their knowledge and connection with the Moore River Estuary?

Appendix C: Survey Instrument (Questionnaire)

NAME: .....GENDER: MALE☐ FEMALE☐ OTHER☐

Consideration of the value of estuarine environments in groundwater management:

Case study Moore River Estuary

Project Aim: To clearly identify the value of the Moore River Estuary to the local community and the condition that needs to be maintained to continue to provide this value.

Questionnaire

1. Your age?
   - ☐ 17 yrs or less
   - ☐ 18-25 yrs
   - ☐ 26-35 yrs
   - ☐ 36-45 yrs
   - ☐ 46-55 yrs
   - ☐ 56-65 yrs
   - ☐ 66-75 yrs
   - ☐ 76 yrs or more
2. Are you a resident or a visitor?
   - ☐ Full-time resident
   - ☐ Part-time resident (e.g. holiday home)
   - ☐ Visitor. Where are you visiting from? Country _____ State _____ Postcode _____
3. For how long have you been visiting the estuary?
   - ☐ First time
   - ☐ Less than 3 years
   - ☐ 3 to 10 years
   - ☐ Greater than 10 years
4. How often do you visit the Moore River Estuary?
   - ☐ First time
   - ☐ Every 5-10 years or more
   - ☐ Every 1-5 years
   - ☐ Every year
5. Do you typically come at the same time of the year when you visit? *First time visitors skip this question*
   - ☐ Yes
   - ☐ No

   If yes, when do you visit and why do you visit at that time? _____

   _____

NAME: .....GENDER: MALE☐ FEMALE☐ OTHER☐

6. Why is the Moore River Estuary important to you? *(tick all that apply)*

☐ Beautiful scenery

☐ Quiet and peaceful

☐ Getaway close to Perth

☐ Cultural significance

☐ Recreational activities

☐ Unique environment and wildlife

☐ Good location for my business

☐ Safe area for recreation e.g. shallow water and sheltered areas from wind

☐ Other reasons (please mention) _____

7. What activities do you like to do at the Moore River Estuary?*(tick all that apply)*

☐ Swimming

☐ Kayaking / canoeing

☐ Sandboarding / sand-sliding

☐ Boating (motored)

☐ Fishing

☐ Viewing scenery

☐ Walk trails

☐ Guided tours

☐ Visiting cafes and restaurants

☐ Camping

☐ Other _____

8. What areas of the estuary do you use? (*Circle on map on the final page or list sites of use*)

_____

9. Is your enjoyment of the estuary affected by the sandbar being open?

☐ Yes. How? _____

☐ No.

☐ I don't know

NAME: .....GENDER: MALE☐ FEMALE☐ OTHER☐

10. What is it about the water in the estuary that allows you to use it the way you do?

(*Tick all options that apply)*

☐ Good appearance (colour, smell, absence of algae)

☐ Water quality that is suitable for human recreation

☐ Provides a good overall water level or a required depth at a location of use

☐ Supports nice riverbank vegetation

☐ Supports fish

☐ Other _____

11. Please rate the following in order of importance for your enjoyment of the estuary

How important is…	**Not important**	**Of some importance**	**Very important**	**Absolutely essential**
Appearance (colour, smell, absence of algae)	☐	☐	☐	☐
Water quality for human recreation e.g. swimming	☐	☐	☐	☐
Overall water level of the estuary or required depth at a location of use	☐	☐	☐	☐
Nice riverbank vegetation	☐	☐	☐	☐
Presence of fish in the estuary	☐	☐	☐	☐

12. Are you satisfied with the current state of the following factors in the Moore River Estuary? If not, state why.

a) Appearance of water: Yes ☐ No ☐ _____

b) Water quality for recreation: Yes ☐ No ☐ _____

_____

c) Overall water level or depth at location of use: Yes ☐ No ☐

_____

d) Riverbank vegetation: Yes☐ No☐ _____

_____

e) Presence of fish: Yes☐ No☐ _____

_____

f) Other _____

_____

NAME: .....GENDER: MALE☐ FEMALE☐ OTHER☐

First time visitors, please now go straight to question 16

13. Have you noticed any change in the condition of the Moore River Estuary over the time you have been visiting? *Consider: overall water level height, water depth in specific areas of use, smell, appearance, presence of algae, colour, presence of fish, riverbank vegetation, natural timing of opening/closing of sandbar.*

    ☐ Yes. What change and since when? _____

    _____

    ☐ No

    ☐ I don't know

14. Have you noticed any significant changes in the condition of the Moore River Estuary in the summer months since 2010? *Consider: overall water level height, water depth in specific areas of use, smell, appearance, presence of algae, colour, presence of fish, riverbank vegetation, timing of opening/closing of sandbar.*

    ☐ Yes. What change and when? _____

    _____

    ☐ No

    ☐ I don't know

15. Was there a time in years past when you were happier with the condition of the estuary?

    ☐ Yes. When and why were you happier? _____

    _____

    Has this impacted how often you visit the estuary? _____

    _____

    ☐ No

    ☐ I don't know.

16. Have you noticed a change in the number of people visiting the estuary?

    ☐ Yes. Describe (*Can be a trend or change in point in time*) _____

    _____

    ☐ No

    ☐ I don't know

NAME: .....GENDER: MALE☐ FEMALE☐ OTHER☐

17. What change in the condition of the estuary would stop you from coming to Guilderton (visitors) or enjoying the estuary (local residents)? *(tick all that apply)*

☐ The condition of the estuary does not impact my willingness to visit or enjoy it.

☐ Water levels too low to undertake an activity you enjoy. Describe *(What activity and how impacted)*

_____

_____

☐ Water quality not safe for human recreation e.g. swimming

☐ Impact to the appearance and smell of the water body

☐ Impact to fish health and loss of fish species

☐ Loss of riverbank vegetation or deterioration in appearance

☐ Other _____