Water Services in the Coastal Tourism Zone of Gunungkidul Karst

Candidate Number: 1083405
Word Count: 29,989

Thesis submitted in partial fulfilment
of the requirements for the Degree of

Master of Philosophy in Water Science, Policy and Management

University of Oxford

Trinity 2025

School of Geography and the Environment

MSc Dissertation/MPhil Thesis

Coversheet

Candidate Number: 1083405

MSc/MPhil course: MPhil in Water Science, Policy and Management

Dissertation Title: Water Services in the Coastal Tourism Zone of Gunungkidul Karst

Word count: 29,989 words

WATER SERVICES IN THE COASTAL TOURISM ZONE OF GUNUNGKIDUL KARST

ABSTRACT

Coastal tourism holds significant economic contributions to a water-scarce area of Gunungkidul karst. With over 60 coastal destinations, the region is expected to experience continued coastal development as planned by local officials, amidst vulnerability to water-related issues rooted in a series of water scarcity and drought events. In light of the potential climate threats and tourism boom, further investigation of coastal tourism is essential. This study qualitatively explores the existing landscape of water services in the coastal tourism zone of Gunungkidul karst and simultaneously identifies the main problems and outlines the appropriate interventions. Multistakeholder interviews were undertaken, including individual interviews with local vendors across the selected beaches and subsequently analysed using thematic and spatial analysis. The results revealed that water services vary irregularly across different tourism zones and coastal development states. Although the coastal tourism in the region has not exhibited massive tourism growth, the water services available in the region have not adequately supplied water for tourism activities. The regional drinking water utility (PDAM) serves as the main water provider in most areas, despite seasonal reliability and water quality issues. Meanwhile, some beaches have limited access to PDAM and prefer less budget-friendly options, such as water trucks, which also turn into a more reliable supporting service. A few others have been self-sufficient with their local sources or by making water wells. These phenomena are believed to stem from the karst environment factors, infrastructure barriers, as well as poor water-tourism governance. Locals express greater concern over the current issues than the most influential stakeholders, as selling water services has been their livelihood. Testimonials from local vendors at every beach suggest immediate technical interventions to enhance the water infrastructure, along with non-technical interventions to address the institutional challenges and support the sustained and responsible practice of water services.

Keywords: coastal karst, coastal tourism, water resources, water services, water-tourism

ACKNOWLEDGEMENTS

This dissertation was written against the backdrop of a global crisis, where access to water, a fundamental human right, is becoming increasingly fragile. In many parts of the world, changing climates dry up rivers and reservoirs; in others, communities are deliberately denied water through politics, conflict, and power. The struggle is not only with nature, but also with systems that transform scarcity into suffering. I grew up in a country with abundant water, yet I witnessed firsthand how access can be fragmented and disproportionately distributed. Experiencing these disparities every day made the issue feel close to me and motivated my desire to contribute to solutions through this research, for undertaking this research has been a constant reminder that my work is not merely an academic pursuit, but part of a broader moral responsibility. This work is dedicated to those who face water insecurity not by chance, but by design and to all who continue to fight for a more just and sustainable future. With that in mind, I wish to express my deepest gratitude to all who have made this journey possible:

1. To Allaah the Almighty, for His will, strength, and guidance throughout every stage of this journey. Without His grace, perseverance, and blessings, this work could not have been completed.
2. To my supervisor, Dr Kevin Grecksch, for invaluable guidance, patience, constructive feedback, expertise, and inspiration throughout these two years of my master's degree. Despite his busy schedule, he consistently made time for one-on-one sessions to address my concerns, clarify doubts, and provide mentorship. I am deeply indebted to him for his dedication, which not only strengthened the academic rigour of this dissertation but also guided me personally, giving me the confidence and clarity to navigate the challenges of research and graduate study.
3. To the Jardine Foundation, for their generous scholarship, enabling me to pursue a master's degree at the prestigious University of Oxford.
4. To the School of Geography and the Environment of the University of Oxford, for providing me with academic guidance and institutional assistance, including the grant to support my research fieldwork.
5. To Oriel College of the University of Oxford, where I spent my 2 years living in a vibrant community, for their dedication to cultivating a scholarly environment where I was able to grow both personally and professionally. I am also incredibly thankful for the travel grants provided to support my overseas fieldwork.

6. To all academic staff, researchers, and professional services staff I have encountered along my master's program, for their assistance, guidance, and support in both administrative and academic matters. Their dedication and professionalism have made my journey smoother and more enriching.
7. To my lecturer in my previous degree, Dr Danang Sri Hadmoko, S.Si., M.Sc., for assisting me in approaching the stakeholders during my research fieldwork. His inspiration set me on this path and reminded me of the purpose of scholarly pursuit.
8. To my local guide during fieldwork, Gilang Cahya Nusantara, for the practical assistance, cultural insight, and logistical support. Without such dedicated help, research in the challenging terrain of Gunungkidul karst would not have been feasible.
9. To the participants of my research, for generously sharing their time, experiences, and perspectives. Their voices and realities form the foundation of this study and give it meaning beyond the academic.
10. To my former colleagues, Mas Ridho and Mas Widi, for engaging in thoughtful discussions about local water stakeholders, and Mas Habibi, who provided me with GIS tips, despite a 6 to 7-hour time difference. I am grateful to Indri and Noverita for accompanying my work whilst I was in Indonesia. I am also thankful for Salman, who helped me connect with an Indonesian NGO for my research fieldwork.
11. To my parents, Soenarto and Idawati, and my sister, Rizka Citra Mulia, my greatest support system, for their unconditional love, prayers, and unwavering support. Thank you for always believing in me, motivating me, and most importantly, for always seeing me as a whole person, with strengths and flaws alike. I hope I have made you proud, and I ask that you continue to support me in my next adventures.
12. To my cohort friends, WSPM 2023 and 2024, for sharing this academic journey side by side. Their camaraderie, mutual support, and shared struggles made the path more bearable and meaningful.
13. To my special peer support group, Wynne Wijaya, Avinindita Nura Lestari, and Nisrina Nur Fatiha, for the dramatic day trips, impromptu binge-café-ing, and occasional formal halls. I will always cherish every high and low that we shared during our time in Oxford.
14. To my landlord, Christopher, for a comfortable and well-equipped home to work from.
15. To all whose names I cannot mention one by one, for every act of kindness, encouragement, or assistance, whether large or small, that helped me to persevere and complete this degree.

To all who have been here with me, *matur sembah nuwun, terima kasih*.

TABLE OF CONTENTS

COVERSHEET i
ABSTRACT ii
ACKNOWLEDGEMENTS iii
TABLE OF CONTENTS v
LIST OF TABLES vii
LIST OF FIGURES viii
LIST OF ABBREVIATIONS x
LIST OF APPENDICES xii
SECTION I INTRODUCTION 1
1.1 Background 1
1.2 Aim, Scope, and Research Questions 5
1.3 Limitation 6
SECTION II LITERATURE REVIEW 7
2.1 Theoretical Framework 7
2.2 Karst Hydrogeology 7
2.3 Geological, Hydrological, and Geomorphological Features of Gunungkidul Karst 11
2.4 Coastal Typology in Gunungkidul Karst 14
2.5 Water Resources from the Lens of Tourism 17
2.6 Water Service in Coastal Tourism System 22
2.7 Water Service in Coastal Karst of Gunungkidul 26
2.8 Previous Research 29
2.9 Research Gaps 30
SECTION III METHODS AND MATERIALS 31
3.1 Research Design 31
3.1.1 Epistemology 31
3.1.2 Methodology and Conceptual Framework 31
3.1.3 Methods 33
3.1.4 Research Tools 35
3.2 Study Area 35
3.3 Data Collection 36
3.3.1 Data Collection Methods 36
3.3.2 Sampling Design 37
3.3.3 Interview Guideline 46

3.3.4 Respondents 47
3.4 Data Processing and Analysis 49
3.4.1 Data Processing Methods 49
3.4.2 Data Analysis Methods 50
3.5 Ethical Considerations 50
SECTION IV RESULTS AND DISCUSSION 52
4.1 Existing Water Service Landscape in Coastal Tourism of Gunungkidul Karst (Research Question 1: How is the variation of water service systems for tourism activities across the coastal zone of Gunungkidul?) 52
4.1.1 Theme 1: Overview of Coastal Karst Landscape Features 52
4.1.2 Theme 2: Coastal Karst Tourism Development 55
4.1.3 Theme 3: Water Governance and Policy in Coastal Karst Tourism 59
4.1.4 Theme 4: Variation of Water Service Across Coastal Karst Tourism 62
4.1.5 Theme 5: Wastewater Management in Coastal Karst Tourism 82
4.2 Present Challenges of Water Service in Coastal Tourism of Gunungkidul Karst (Research Question 2: What challenges threaten the water service operations for tourism in the Gunungkidul coasts?) 88
4.2.1 Theme 1: Internal Challenges 88
4.2.2 Theme 2: External Challenges 91
4.3 Addressing the Current Water Issues of Coastal Tourism in Gunungkidul Karst (Research Question 3: In what ways do the corresponding stakeholders effectively address the present challenges to enhance future planning and implementation?) 97
4.3.1 Theme 1: Technical Interventions 97
4.3.2 Theme 2: Non-Technical Interventions 101
SECTION V CONCLUSION 104
5.1 Summary 104
5.2 Recommendation 105
REFERENCES 107
APPENDICES 125

LIST OF TABLES

Table 2.3.1 Epikarst Zone Characteristics Based on Its Porosity……13
Table 2.3.2 Characteristics of the Hydrogeological Unit in Gunungkidul Karst.……14
Table 2.4.1 Coastal Typology Classification.……...15
Table 2.8.1 Previous Research on Coastal Tourism in Gunungkidul Karst.……29
Table 3.3.2.1 Strategic Tourism Zone and Coastal Tourist Destinations.……38
Table 3.3.2.2 Coastal Typology of Coastal Attraction in Gunungkidul.……..38
Table 3.3.2.3 Assessment of TALC Stage in Cairns, Queensland, Australia.……..40
Table 3.3.2.4 4A Components of Coastal Attractions in Gunungkidul.……...42
Table 3.3.2.5 Tourism Area's Stage of Coastal Attractions in Gunungkidul.……...45
Table 3.3.2.6 Sampling Location.……46

LIST OF FIGURES

Figure 1.1.1 Gunungkidul Karst Map...……...3
Figure 2.2.1 Comprehensive Karst System Illustration...……8
Figure 2.2.2 Karst System Conceptual Model...…….10
Figure 2.3.1 Map of Geomorphology of the Special Region of Yogyakarta..……12
Figure 2.3.2 Lithology Map of Gunungkidul Karst...…….12
Figure 2.3.3 Map of the Hydrogeological Unit in Gunungkidul Karst....……...13
Figure 2.5.1 Butler's Tourist Area Life Cycle Curve....……..19
Figure 3.1.2.1 Social-ecological System Between Landscape and Tourism....……...32
Figure 3.1.2.2 Conceptual Framework...…….……33
Figure 3.1.3.1 Research Flowchart...…….……..34
Figure 3.2.1 Study Area.…….…….....36
Figure 4.1.2.1 Coast Built by Organism: (a) Ngrenehan Beach, (b) Nguyahan Beach, Land Erosion Coast: (c) Gesing Beach...……..56
Figure 4.1.2.2 Structurally-shaped Coast: Ngunggah Beach….……....57
Figure 4.1.2.3 Marine Deposition Coast: (a) Watu Kodok Beach, Wave Erosion Coast: (b) Drini Beach.……..57
Figure 4.1.2.4 Wave Erosion Coast: (a) Jungwok Beach, Volcanic Coast: (b) Siung Beach.....58
Figure 4.1.4.1 Proportions of Water Source Used in the Gunungkidul Coastal Tourism....……64
Figure 4.1.4.2 Water Sources in (a) Nglambor Beach, (b) Potunggal Beach.…….……65
Figure 4.1.4.3 Underground River in Baron Beach: (a) The Outlet, (b) Rock Fissure, (c) Transmission Pipeline (Transporting Raw Water to the Utility).……66
Figure 4.1.4.4 Proportions of Water Source Used for Drinking Water in the Gunungkidul Coastal Tourism..…….66
Figure 4.1.4.5 Gallon/bottled Water Delivered by Local Transport..……..67
Figure 4.1.4.6 Proportions of Primary Water Sources in the Gunungkidul Coastal Tourism.…70
Figure 4.1.4.7 Rainwater Harvesting...……72
Figure 4.1.4.8 Proportion of Primary Water Provider in Gunungkidul Coastal Tourism..……..72
Figure 4.1.4.9 (a) Bore Well in Siung Beach, (b) Dug Well in Krakal Beach...……...73
Figure 4.1.4.10 (a) Puring Source, (b) Concrete Water Storage, (c) Water Truck...……74
Figure 4.1.4.11 Water Tariff Comparison between (a) PDAM/SPAMDes and (b) Water Truck in the Coastal Tourism Zone of Gunungkidul Karst (in Indonesian rupiahs)..……78

Figure 4.1.4.12 Map of Primary Water Service in the Coastal Tourism Zone of Gunungkidul Karst……79
Figure 4.1.4.13 Water Service in the Coastal Tourism Zone of Gunungkidul Karst..……81
Figure 4.1.4.14 Water Storage Tanks..……82
Figure 4.1.5.1 Small River for Wastewater Disposal.……84
Figure 4.1.5.2 Cross-sectional Profile of Conventional Semi-Open Septic Tank.……..85
Figure 4.1.5.3 Polluted River near Drini Beach.……87

LIST OF ABBREVIATIONS

ABBREVIATION	DEFINITION
ABSAH	Akuifer Buatan Simpanan Air Hujan (Standardised Artificial Aquifer Programme for Rainwater Storage)
A.G.U.A	Acciones para la Gestión y el Uso del Agua (Actions for the Management and Use of Water)
ASEAN	Association of Southeast Asia Nations
BBWS	Balai Besar Wilayah Sungai (River Basin Organisation)
BPDAS	Balai Pengelolaan Daerah Aliran Sungai (Watershed Management Agency)
CUREC	Central University Research Ethics Committee
DIKPLHD	Dokumen Informasi Kinerja Pengelolaan Lingkungan Hidup Daerah (Regional Environmental Performance Information Document)
DIY	Daerah Istimewa Yogyakarta (Special Region of Yogyakarta)
ENSO	El Niño-Southern Oscillation
ETIS	European Tourism Indicator System
EU	European Union
GDP	Gross Domestic Product
GGN	Global Geopark Network
GIS	Geographic Information System
GSTC	Global Sustainable Tourism Council
JICA	Japan International Cooperation Agency
KSMS	Karst Submarine Springs
LEDCs	Less Economically Developed Countries
MEDCs	More Economically Developed Countries
MINAE	Ministerio de Ambiente y Energía (Ministry of Environment and Energy)
NGOs	Non-Governmental Organisations
PAMSIMAS	Penyediaan Air Minum dan Sanitasi Berbasis Masyarakat (Community-based Drinking Water and Sanitation Programme)
PDAM	Perusahaan Daerah Air Minum (Regional Drinking Water Utility)
POKDARWIS	Kelompok Sadar Wisata (Tourism Awareness Group)
RBO	River Basin Organisation
RENJA	Rencana Kerja (Work Plan)
RENSTRA	Rencana Strategis (Strategic Plan)

RPPLH	Rencana Perlindungan dan Pengelolaan Lingkungan Hidup (Environmental Protection and Management Plan)
RTRW	Rencana Tata Ruang Wilayah (Regional and Spatial Plan Policy)
SESs	Social-Ecological Systems
SINAC	Sistema Nacional de Areas de Conservación (National System of Conservation Areas)
SLR	Sea Level Rise
SPAMDes	Sistem Penyediaan Air Minum Perdesaan (Rural Drinking Water Provision System)
SPAL	Sistem Pengelolaan Air Limbah (Wastewater Management System)
SPPL	Surat Pernyataan Kesanggupan Pengelolaan dan Pemantauan Lingkungan Hidup (Statement of Environmental Management and Monitoring Capability)
SRN	Sistem Registri Nasional (National Registry System)
TALC	Tourism Area Life Cycle
TEV	Total Economic Value
UKL-UPL	Upaya Pengelolaan dan Pemantauan Lingkungan Hidup (Efforts for Environmental Management and Monitoring)
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNWTO	United Nations World Tourism Organisation
USACE	United States Army Corps of Engineers
WALHI	Wahana Lingkungan Hidup Indonesia (The Indonesian Forum for Environment)
WASH	Water, Sanitation, and Hygiene
WTP	Water Treatment Plant

LIST OF APPENDICES

Appendix I: Ethical Clearance Approval from the Corresponding Officials.……125
Appendix II: Participant Information Sheet.……..126
Appendix III: Oral Consent Form.…….129
Appendix IV: Oral Consent Script.……130
Appendix V: Interview Guideline.…….132

SECTION I
INTRODUCTION

1.1 Background

Coastal tourism appears to be the economic backbone of most coastal or waterfront states (Ye, 2023). Coastal tourism is no longer a seasonally privileged activity, as tourism expands and becomes a strategic sector of a region. Greece and Spain are amongst the Mediterranean countries suffering from water scarcity, and it is worsening due to increasingly strong demand for coastal tourism and growing threats of climate change (Kakoulas et al., 2022). In Bartolomé de Tirajana (Canary Islands), 213 non-resident accommodations face challenges in water conservation initiatives (Padrón-Fumero et al., 2025). Similarly, Indonesia is one of the premier all-season destinations, which also encounters challenging water resource issues in its tourism sector. Bali's charm has attracted mass tourism that triggers water competition between locals and external stakeholders (Strauß, 2011). Relatively close to Bali is the emerging coastal gem, Gunungkidul. This region has witnessed the development of 62 beaches as tourist destinations for both national and international visitors, despite its water-scarce landscape (karst) and recorded history of droughts. These phenomena have raised concerns about how water services can be effectively sustained and how they vary in a complex environment like Gunungkidul. Through this research, the study will contribute to understanding the variation of water service landscapes and the present challenges across multiple tourist destinations in the coastal tourism zone of Gunungkidul karst.

The weather and climate properties significantly influence the relationship between the natural landscape and anthropogenic activities. Indonesia is the largest archipelagic state in the world, situated in the tropical regime, receiving a substantial amount of precipitation, ranging from 3,000 to 5,000 mm, a salient aspect of its freshwater resources (Badan Meteorologi, Klimatologi, dan Geofisika, 2021). Indonesia is also recognised as a great maritime nation, spanning its territory from west to east between the continents of Asia and Australia, and the Pacific and the Indian Ocean. The islands formed in a complex geological setting through the interaction of three major tectonic plates: Eurasia, Indo-Australian, and Pacific plates. These contribute to the distinct inland and coastal morphological features, along with the diversity of natural resources, including its water resources. Despite its abundance, the variation in landforms leads to discrepancies in water resources (Mawardi, 2008). Water is a vital resource for citizens across various sectors, including agriculture,

manufacturing, and tourism, which are amongst the country's most productive economic contributors (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2002).

Indonesia's rich archipelago includes onshore and offshore resources. Following the ratification of the 1982 United Nations Convention on the Law of the Sea (UNCLOS), Indonesia's territory expanded to encompass extensive land and surrounding ocean. According to Kementerian Koordinator Bidang Kemaritiman dan Investasi (2023) Indonesia's estimated coastline length reaches 108,000 km, ranking it amongst the top two globally. The heterogeneity of coast typology and the distribution of natural resources along these coastlines represent a significant natural capital for tourism development in Indonesia (Steele et al., 2021).

The tourism sector has been growing as an important source of economic output and a catalyst in global job creation, particularly in developing countries, such as Indonesia (Parlindungan & Manurung, 2023). This industry has been a key contributor to Indonesia's foreign exchange earnings (Hariyani, 2018). Moreover, the tourism sector has stimulated economic growth following the COVID-19 pandemic. The current market value of Indonesia's travel and tourism sector is accounted for 854,541 billion Indonesian rupiahs (approximately 43.73 billion pounds) and is forecast to increase by roughly 600,000 billion Indonesian rupiahs (approximately 30.70 million pounds), reaching approximately 1,404,035 billion Indonesian rupiahs (approximately 71.28 million pounds) by 2027 (PwC Indonesia, 2023). This significance has led to prioritising the tourism sector, including coastal tourism development. As of 2023, the Indonesian Government, through the Ministry of Finance, has allocated over 3.5 trillion Indonesian rupiahs (approximately 177.68 million pounds) to tourism, making it one of the top five priorities of the current cabinet's work programmes (Kementerian Keuangan, 2023).

Gunungkidul Regency (an administrative region within a province, equivalent to a city) in the Special Region of Yogyakarta (DIY) Province, demonstrates promising potential for future economic development due to its total economic value (TEV), estimated at 3.14 billion Indonesian rupiahs (approximately 158 thousand pounds) (Triyanti & Susilowati, 2018). This region has transformed into a coastal tourism hotspot in recent years. According to data from Gunungkidul's Tourism Office, recorded in Gunungkidul Regency in Figures of 2006 and 2023, visitor numbers increased from just 271,321 at the start of the period to over 2 million in the final year, more than seven times higher than in 2006 (Badan Pusat Statistik Kabupaten Gunungkidul, 2006, 2023). The importance of coastal tourism is reflected in its 26% contribution to the regional gross domestic product (GDP) (Aji, 2019). The local government

has also increased investment, allocating over 20 billion Indonesian rupiahs (approximately 960,000 pounds) to tourism development (Dinas Pariwisata Kabupaten Gunungkidul, 2024). This initiative aims to generate revenue from coastal tourism to boost the regional economy.

Gunungkidul coasts stretch along the southern part of the region, forming the boundary of the Karst Gunung Sewu (Southern Mountains Karst Global Geopark), which is formally recognised as a Global Geopark Network (GGN) by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) (Figure 1.1.1). The coastline extends from east to west along the Indian Ocean. This more than 70 kilometres coastline (the longest portion of the province) includes notable coast typologies, from cliffs to sandy beaches. According to a report published by Dinas Pariwisata Kabupaten Gunungkidul (2022), there are 110 beaches designated as tourist attractions, 62 of which are already recognised as official tourism sites, and the remaining 58 are planned for future development to attract more visitors, both domestic and international.

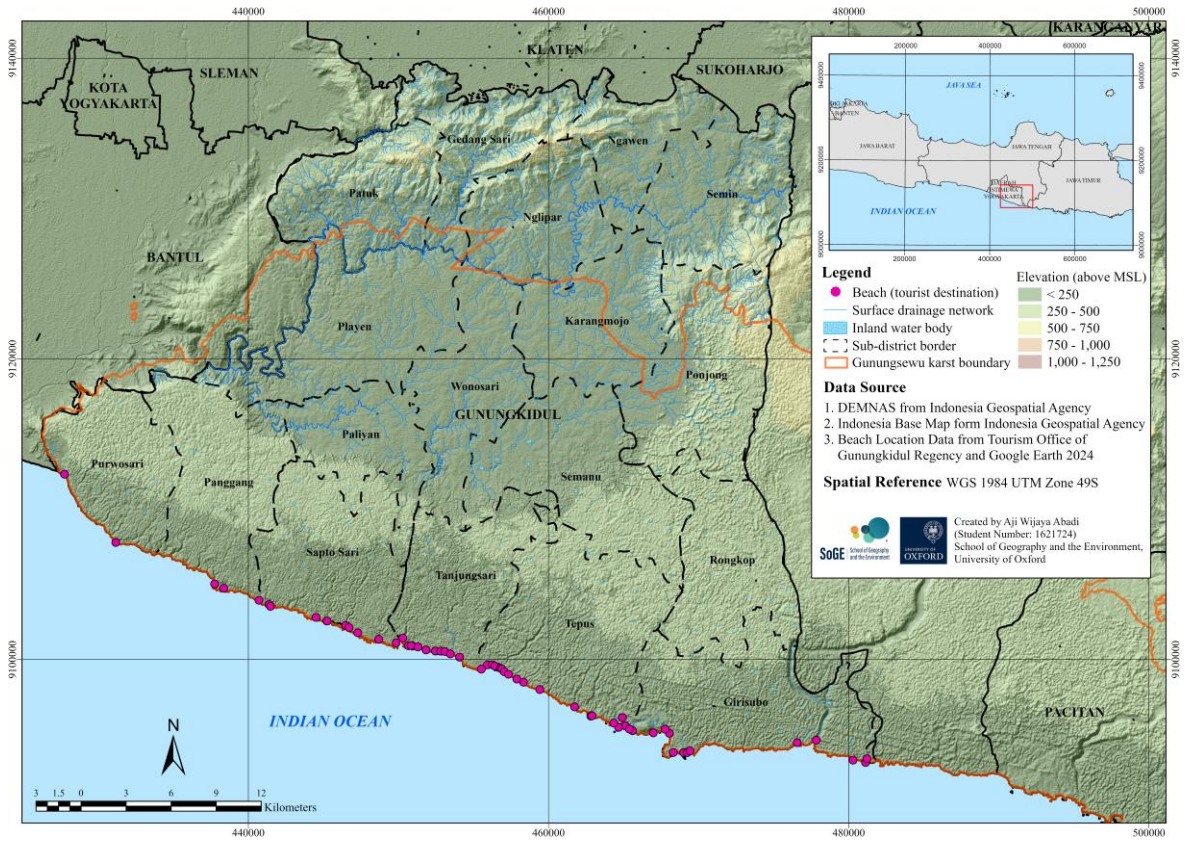


Figure 1.1.1 Gunungkidul Karst Map

Source: Courtesy of the Author (2025)

The increasing tourism activities in the region drive a significant rise in the demand for basic facilities and supporting infrastructure, including water services. The scale and intensity

of water demand for tourism depend on the types of activities, accommodation, and attractions available at the tourism site, indicating that adequate water services are essential to meet this growing demand (Liu et al., 2021; Sun & Hsu, 2019). Water service is crucial for supporting tourism operations, as an increase in population requires water for various purposes, such as drinking, cleaning and hygiene, recreation, food provision, and other services (Becken, 2014). In a developing tourism area, destinations with higher quality or standards of accommodation and all-inclusive businesses tend to drive water-intensive tourism, resulting in substantial growth in water consumption (Gössling, 2015; Vila et al., 2018). However, tourists are often oblivious to water scarcity issues in the vicinity of tourist destinations, whilst their experience in accessing water affects the sustainability of tourism industries (D'Ascenzo et al., 2020).

Natural attractions are central to coastal tourism, which is considered the most vital segment of the tourism industry, as roughly 30% of global tourism sites are concentrated on coastlines or in coastal zones, attracting many travellers and fostering local economic benefits and cross-border exchanges (Carvache-Franco et al., 2022; Ghosh, 2012; Rutty & Scott, 2016). Coastal tourism is particularly popular in Gunungkidul due to its diverse coastal landscape, ranging from sandy coasts to cliffs. Locals have developed and managed many coastal tourism sites independently, advertising beaches equipped with various engaging activities, such as seaside-view resorts, camping grounds, or day-trip sightseeing.

The natural landscape of Gunungkidul includes extensive dry karst hills, mountains, caves, and closed depressions (Kusumayudha et al., 2015). Karstic regimes are inherently prone to unfavourable geomorphological and hydro-climatological constraints, regularly causing water scarcity (Wang et al., 2025). Gunungkidul lies within a tropical monsoon climate, with uneven rainfall distribution and periodic influence from the El Niño-Southern Oscillation (ENSO), resulting in wetter conditions during La Niña years and opposite conditions during El Niño years (Brunsch et al., 2011 in Eiche et al., 2016). Consequently, water availability in the region remains uncertain due to vulnerability to climate variability, which influences water presence based on landscape factors. Water primarily exists beneath the surface in the underground stream network, whilst a marginal surface water exists in dolines or *telaga* (small lakes) (Ariyanti et al., 2014). The topography facilitates continuous dissolution of karst landforms, reducing surface runoff and surface water retention, thereby increasing the risk of water shortages in karst areas (Qin et al., 2015). Historically, most water shortages have resulted from excessive water use, but future risks are expected to worsen due to climate change impacts (Greve et al., 2018). Rising global temperatures caused

by climate change have led to unprecedented water supply problems and stress in many water-scarce regions (Zhu et al., 2024 in Wang et al., 2025). The complex interaction between climate change and karst hydrology disrupts groundwater recharge, deteriorates water quality, and alters water availability (Rose, 2022; Hartmann et al., 2020; Setiawan et al., 2021). These factors suggest that climate change could significantly influence groundwater dynamics and intensify water scarcity issues in regions like Gunungkidul.

Several water scarcity events have been reported in Gunungkidul, primarily driven by natural forces. In 2023, 16 of the 18 districts experienced water shortages, with only Wonosari and Playen District still having sufficient water sources (JPNN, 2023). Some parts of the region heavily depend on surface water from *telaga* (small lakes) and *embung* (public ponds). The region has approximately 359 *telaga*, but during last year's drought, 344 dried up and could not meet domestic water needs (Detik News, 2023). As this situation persisted for months, approximately 118,000 people faced difficulties obtaining adequate water (Harian Jogja, 2023). The local government responded by distributing 3,148 water tanks to assist affected people (Kompas, 2023).

Meanwhile, the expanding coastal tourism sector has increased pressure on the already strained water supply, especially during the dry season. This situation may worsen due to climate change, with rising water demand driven by tourism growth, making resource management more difficult. This also impacts the provision of sufficient water services critical for meeting community needs. Furthermore, the government plans to develop 58 additional beaches as tourist attractions, highlighting the importance of ensuring these sites are properly supplied with water. Coastal tourism faces risks linked to climate change, such as rising temperature and sea level rise (SLR), which can disrupt tourism seasons and increase vulnerability of tourism enterprises, as there are numerous mechanisms by which climate intervenes in water availability and consumption in tourist destinations, making it tougher to arrange the appropriate measures (Hadjikakou et al., 2013; Haldane et al., 2023; Mackay & Spencer, 2017; Pandy & Rogerson, 2021; Turp et al., 2024). Consequently, addressing water service challenges is essential. As water scarcity persists in Gunungkidul, further research into the dynamics of coastal tourism is needed to ensure that the sector can sustainably supply water for tourism activities without compromising local water supplies.

1.2 Aim, Scope, and Research Questions

The research aims to investigate the water service systems and their challenges in coastal tourism and explore how they vary across the Gunungkidul coasts. This research will

focus on the dynamics of water issues in light of the expanding coastal tourism activities along the Gunungkidul coastal area from a social-ecological perspective. The result will academically construct a firmer understanding of the interdisciplinary water issues within the water-tourism nexus, particularly in a water-scarcity-prone region such as Gunungkidul. The findings can also guide the local governing institutions involved in coastal planning in addressing problems that threaten the sustainability of water services in coastal areas. The policymaker can incorporate the findings in the decision-making process to better understand the complexity and address the issues appropriately, concerning their plan for developing tourist attractions in the coastal area. Three research questions are brought up to answer the main issue of this research, as follows:

1. How is the variation of water service systems for tourism activities across the coastal zone of Gunungkidul?
2. What challenges threaten the water service operations for tourism in the Gunungkidul coasts?
3. In what ways do the corresponding stakeholders effectively address the present challenges to enhance future planning and implementation?

1.3 Limitation

The state of research on the water-tourism nexus in Indonesia is currently underdeveloped, particularly in a complex environment such as coastal karst. The limited availability of prior scholarly work in this area presents a significant barrier to conducting a more detailed and nuanced empirical approach. Moreover, the intricacies of water sectors and tourism chains in coastal tourism extend beyond a superficial understanding. The interaction within this system exhibits underlying complexities, as many indirect sectors that support tourism industries have been infrequently incorporated in various academic sources. Instead of addressing and covering the limited existing literature and the complex relationship issue of the research topic, a more adaptive approach is adopted in this study.

This research takes place during the dry season in Indonesia, which spans from April to September; hence, variation in the wet season is not thoroughly explored. The dry season setting likely exhibits water challenges in the tourist destinations. Furthermore, the research does not involve tourist arrival statistics at all beaches and the quantitative measures of water supply and demand balance. The research does not incorporate any inland or offshore tourist attractions, as the centre of the research focuses on water services for tourism purposes within the coastal karst environment.

SECTION II
LITERATURE REVIEW

2.1 Theoretical Framework

The water-tourism nexus serves as the underlying theoretical framework of this study, as it lies in the intersection between water resources management and tourism. Ricart et al. (2024) explain that the water-tourism nexus includes any study that focuses on tourism activities across water topics, such as water consumption, water management, and water governance in mass tourism. In light of this, three theories or concepts are of utmost importance in this study: karst hydrology, coastal typology, and tourism development.

Karst hydrology points out the geomorphological structures of the karst landscape that determine the hydrological properties of the region, including water movement, availability, quality, and distribution both on and under the karst surface. Referring to Ford & Williams (2007), the geological features of the karst landscape lead to a high responsiveness of the system towards the hydrological cycle, exhibiting both potential and vulnerability in terms of its water resources. As the scope of the research area focuses on the coastal tourism zone, the concept of coastal typology by Shepard (1937) is adopted, given the intricate dynamics between the coastal and karst landscape along Gunungkidul's coastline. Integrating the coastal typology to complement karst hydrology theory serves as a critical lens to grasp the complexity of water resource characteristics in a more nuanced understanding of multidimensional interaction in the transitional zone, providing deeper insights into the current state of coastal water resources for tourism sectors.

Additionally, this study draws upon the tourism area life cycle (TALC) by Butler (1980), which emphasises the sequence of physical and social changes in tourist destinations arising from tourism activities. TALC reflects the responses of tourism sectors towards growing tourism or increasing tourist arrivals, implicitly conveying the dynamics of resource management in tourism at each stage. In the context of coastal tourism, TALC is of significance to logically explore the implications of coastal tourism behaviour in utilising and managing water resources from one stage to another, which may pose varying states and complications in several areas, such as water demand, water supply and water service.

2.2 Karst Hydrogeology

Water is an essential natural resource whose occurrence is not solely governed by atmospheric circumstances but should also be linked back to the genesis of the landforms.

Water can be found on the Earth's surface and beneath, whose variation, proportion, and domination depend on several parameters, including the geomorphological units, as each unit may differ in its permeability and infiltration levels (Mohammad et al., 2024). Geomorphology of a region shapes the pathways of water movement, such as surface runoff and groundwater recharge, through its distinct structure (Zaimes et al., 2021). Varied topography expressed in a certain geomorphology may respond to differential influences from precipitation, which consequently regulates the underground moisture and runoff formation (Chen et al., 2013). Rainwater infiltrates, remains, and flows through a variety of landforms and determines the water quantity and quality of a region (Sears, 2015). Consequently, the linkages between geomorphological and hydrological processes result in some places on Earth favourably accommodating abundant surface water and groundwater resources, whilst others encounter difficulties in accessing water due to intermittent availability.

Karst geomorphology (Figure 2.2.1) is well-differentiated from non-karst geomorphic systems due to its unique geomorphological processes and derivative landforms. Ford & Williams (2007) define karst as an encompassing terrain characterised by a distinctive interaction between its hydrological processes and landforms, which develops on highly soluble lithology such as limestone, with massive coarsely fractured (porous) and dense rock structure, allowing an intense rock dissolution both on the surface and subterranean systems. The hydrological cycle in the karst system drives the solutional processes within the rocks, fundamentally creating various karst features, such as enclosed depressions, fluted rock outcrops, underground streams, cavern networks, and large springs (Ford & Williams, 2007).

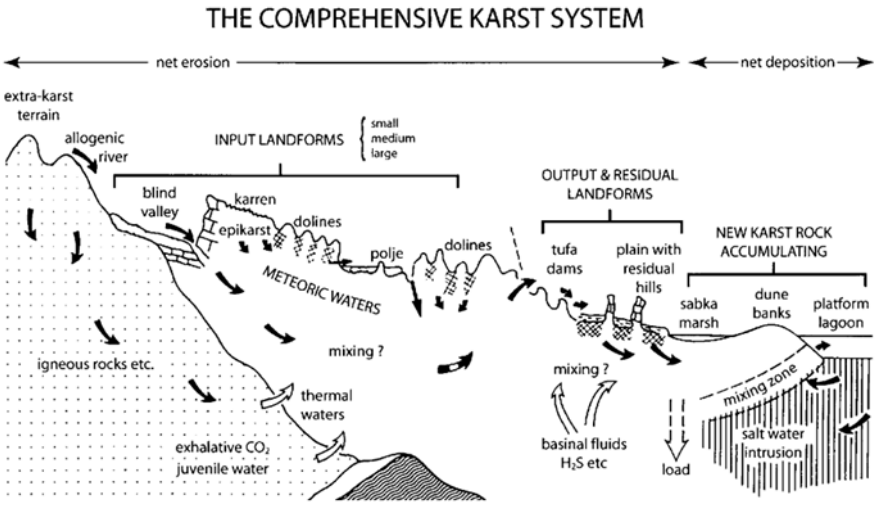


Figure 2.2.1 Comprehensive Karst System Illustration

Source: Ford & Williams (1989) in Ford & Williams (2007)

According to Švara et al. (2022), karst is classified as an active and responsive geomorphology compared to other geomorphologic systems, as the landform is dynamically influenced by geological, hydrological, and climatic factors. The geological structure of the karst system enables the dominance of subsurface hydrological processes and controls the movement of groundwater within the karst aquifers. The fine pores and fractures reflect the geochemistry of the aquifers, which most likely governs the slow-moving water flow, whilst higher-rate flow occurs through conduits or larger fractures as a response to the characteristics of recent storms and surface runoff-driven recharge (Winter et al., 1998). The interconnected fractures and pores in the karst system are also attributable to the disappearance and emergence of surface streams, related to the presence of seeps and springs, and the development of underground rivers, which could have a similar flow rate to surface rivers (Winter et al., 1998). Additionally, these groundwater rivers can either emerge at the coastal zone or discharge directly into the sea at karst submarine springs (KSMS), which are common in areas with coastal karst aquifers, such as the Mediterranean basin (Bakalowicz, 2018). Essentially, groundwater flows resulted from the combined influence of the system's inherent features and the ongoing hydrological cycle.

From a hydrological perspective, karst is regarded as a dry terrain and is ecologically sensitive to various water-related issues. Karst is typified by its limited surface water sources, whilst it contains overflowing water in the subsurface drainage. Despite its vast availability, accessing and managing groundwater in the karst region remains challenging because the complex interconnection of pores, fractures, and conduits contributes to varied recharge mechanisms and flow patterns (Fan et al., 2024; Sappa et al., 2018). Allocca et al. (2014) affirm that the intricacy of karst geological structure often necessitates detailed field exploration to accurately measure coefficients of recharge and infiltration in estimating groundwater availability. The heterogeneity within the aquifers implies irregular groundwater flow, posing challenges in establishing access points for water abstraction (Murgulet et al., 2016).

The development of matrix, conduits, or underground rivers within karst aquifers can complicate the assessment of water quality. As shown in Figure 2.2.2, karst systems have a strong connectivity between surface and subsurface systems because they are interconnected by these matrices and conduits. The complex rock matrix causes variations in recharge areas and groundwater quality (Anggraeni et al., 2023; Charlier et al., 2015). Well-developed karst aquifers feature high permeability, enabling rapid water movement, which can compromise water quality and hinder sustainable access (Zhang et al., 2023; Zhu et al., 2021). The

hydrogeological properties of karst aquifers also demonstrate the system's capacity to respond swiftly to rainfall and storm events, complicating the monitoring of groundwater quality (Goldscheider et al., 2020). Moreover, the interconnected surface and subsurface water systems make this system highly vulnerable to groundwater contamination, as highlighted by Zhong et al. (2023). This connection allows rapid infiltration, so potential surface contaminants can quickly travel within subsurface karst systems (Song et al., 2020; Valente et al., 2022), posing risks to public health and disrupting reliable water access (Anggraeni et al., 2023; Liao et al., 2022). Escolero et al. (2002) as cited in Jakada et al. (2019) confirm that high permeability leads to various practical problems in karst terrain, including water scarcity, unpredictable groundwater supplies, land instability due to sinkhole development, leakage from reservoirs, and issues with waste disposal areas.

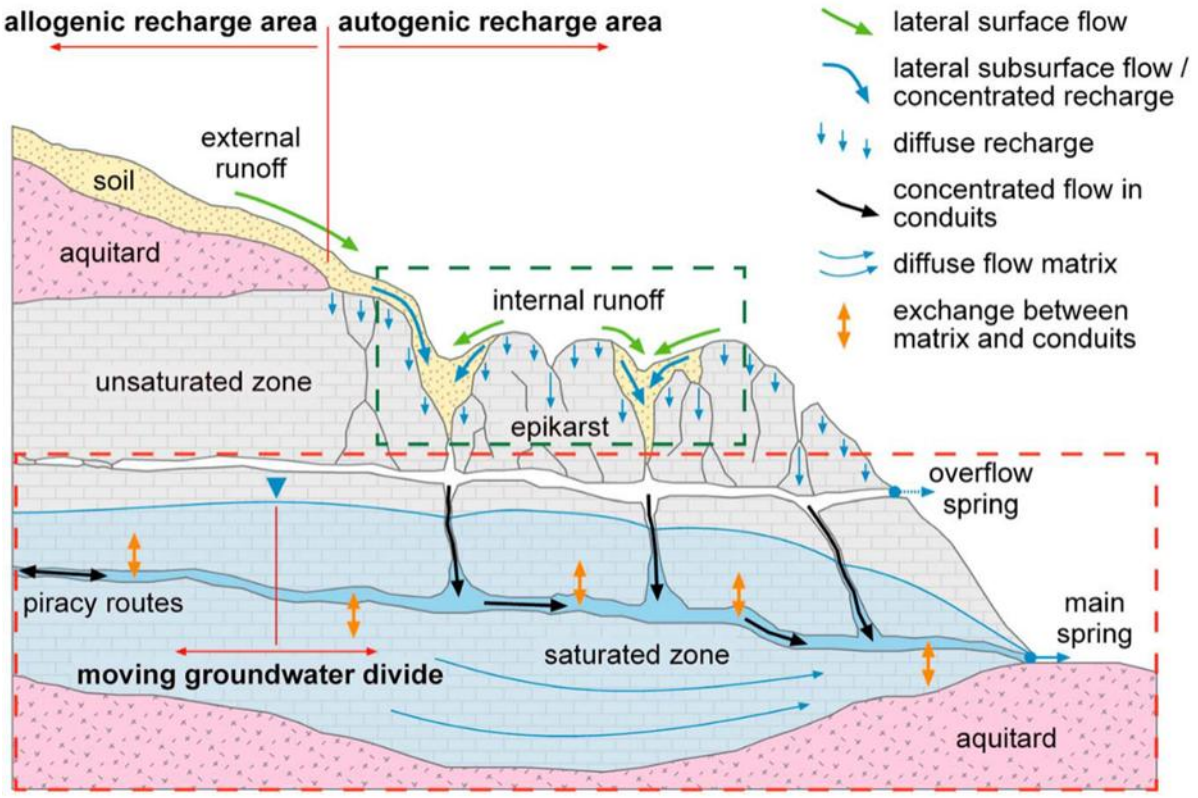


Figure 2.2.2 Karst System Conceptual Model

Source: Hartmann et al. (2014)

Karst's rapid response to hydrological processes indicates high sensitivity to climate change. Climate simulations forecast a dramatic temperature rise and declining precipitation across many karstic regions in the upcoming decades, potentially disrupting hydrological regimes and increasing water stress (Hartmann et al., 2014, 2020). Additionally, the extent to

which climate change influences hydrological dynamics and water availability is understudied (Liu et al., 2021). Precipitation is the main input to both the matrix (slow-moving water flow) and the conduit (fast-moving water flow) systems, and aquifers with well-developed conduit systems are more susceptible to changing rainfall and recharge; thus, triggering abrupt changes of water availability in the discharge points (karst springs or the surface rivers) (Neilson et al., 2018). De Vita et al. (2012) analysed the influence of climate variabilities on groundwater recharge, unveiling a strong correlation between the regional indexes of precipitation, air temperature, and effective precipitation and karst spring discharges. Karst hydrogeological processes are responsive to changes in climatic factors. It resonates with Cheng et al. (2024), emphasising that climatic factors profoundly impact runoff generation and fluctuation in karstic landscapes. Additionally, there is a potential risk of salt intrusion for ocean-facing conduit systems in the coastal karst regime (Liu et al., 2019). Overall, climate change could compromise groundwater recharge and quality in the karst region (Hartmann et al., 2015).

2.3 Geological, Hydrological, and Geomorphological Features of Gunungkidul Karst

The hydrology of Gunungkidul varies, reflecting its complex geological setting. Gunungkidul karst has experienced advanced karstification that shapes tropical karst morphology, mainly conical karst, further described into three variations: labyrinth-cone karst (faultily and jointly influenced), polygonal-cone karst (fluvially influenced), and residual-cone karst (isolated) (Haryono & Day, 2004 in Cahyadi et al., 2017). Figure 2.3.1 shows the distribution of landforms in the DIY Province, including Gunungkidul (highlighted by the red square), a karst landforms-dominant area. The landform varies from plains, valleys, to conical karst, overlaying the Wonosari Formation (Figure 2.3.2) that extends to its coast, under which the limestone has developed since the Middle Miocene (Kusumayudha et al., 2015). This formation consists of over 650 meters-thick limestone, dominated by coralline limestone in the southern part and layered limestone on the other side, overlying the Miocene volcaniclastic sedimentary rocks as its major parent rock layers (Cahyadi et al., 2017).

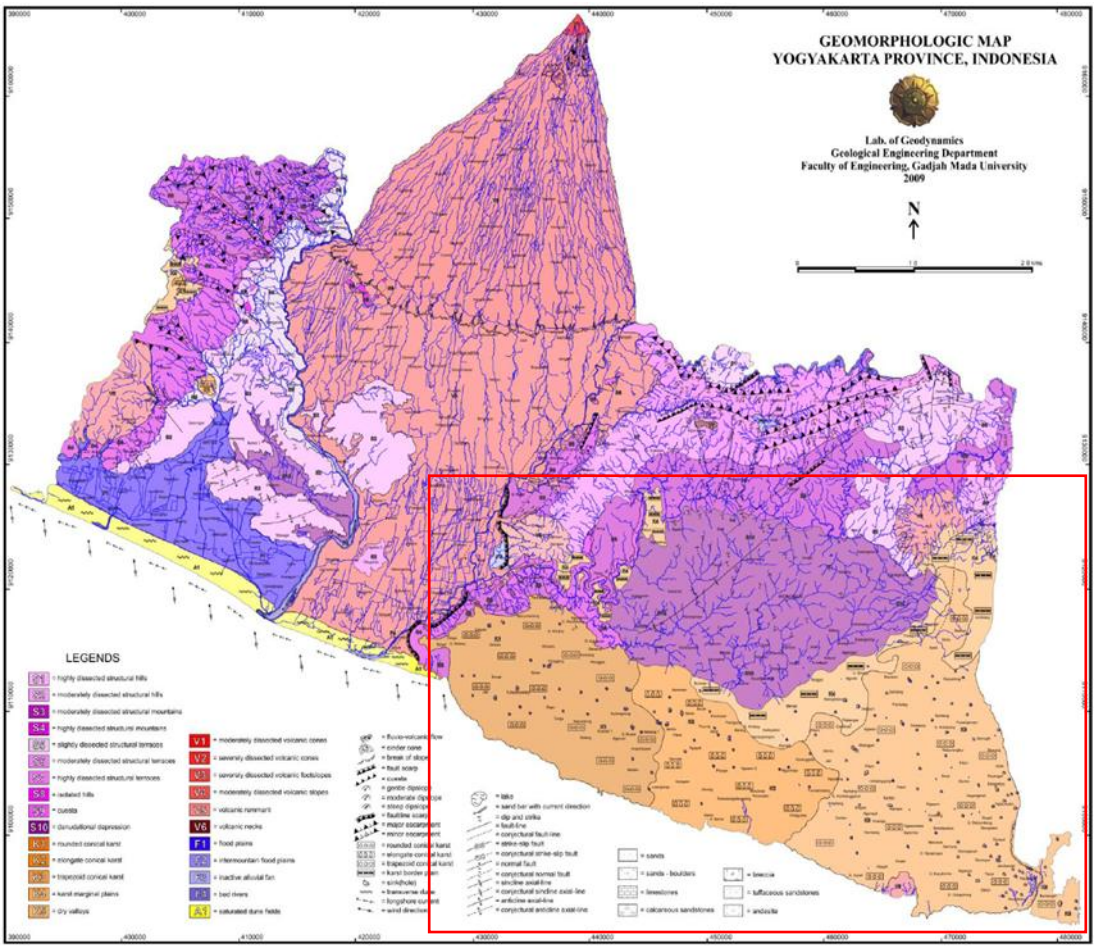


Figure 2.3.1 Map of Geomorphology of the Special Region of Yogyakarta

Source: Husein & Srijono (2010)

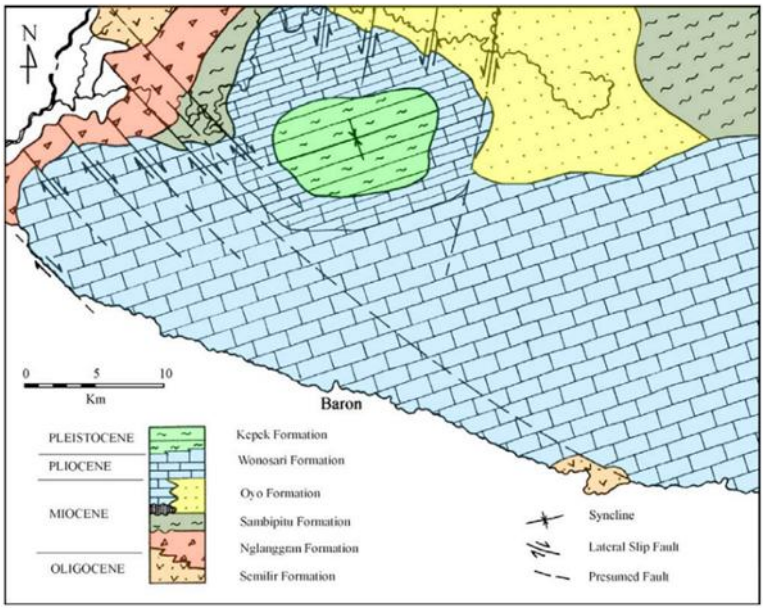


Figure 2.3.2 Lithology Map of Gunungkidul Karst

Source: Kusumayudha et al. (2015)

The geological structure and lithology interact with the hydrological processes, shaping the hydrogeology of Gunungkidul karst. The karst aquifer is primarily fed by conduits that form the subterranean drainage systems, controlled by the enlargement of secondary porosity as a result of the solutional process (Haryono, 2000). Haryono (2000) classifies the epikarst zone (outermost rock layer in karst terrain) based on the porosity and briefly elaborates its hydrogeological properties as per Table 2.3.1.

Table 2.3.1 Epikarst Zone Characteristics Based on Its Porosity

Morphology	Characteristics
Polygonal karst	Shallow, sturdy coralline limestone with well-developed karren and solutional cavities. It is associated with abundant springs that feed the surface water system.
Labyrinth karst	Thick, sturdy coralline limestone with intensive karren and solutional cavities, and associated with an intensive network of dry valleys where no springs emerge.
Tower-cone karst	Thick, weak coralline limestone, less presence of karren, isolated conical karst with planation surface, unfavourable for springs emergence.

Source: Haryono (2000)

Aquifer recharge in Gunungkidul karst typically sources from allogenic flow from surface drainage and point recharge (ponors), and can appear as seasonal springs (Haryono, 2000). Gunungkidul karst constitutes five hydrogeological units: 1) Panggang sub-system, 2) Bribin-Baron-Ngobaran sub-system, 3) Ponjong sub-system, 4) Pracimantoro-Giritontro sub-system, and 5) Donorojo-Pringkuku (Figure 2.3.3). Each subsystem represents unique geological features that manifest in the potential of water resources as described in Table 2.3.2.

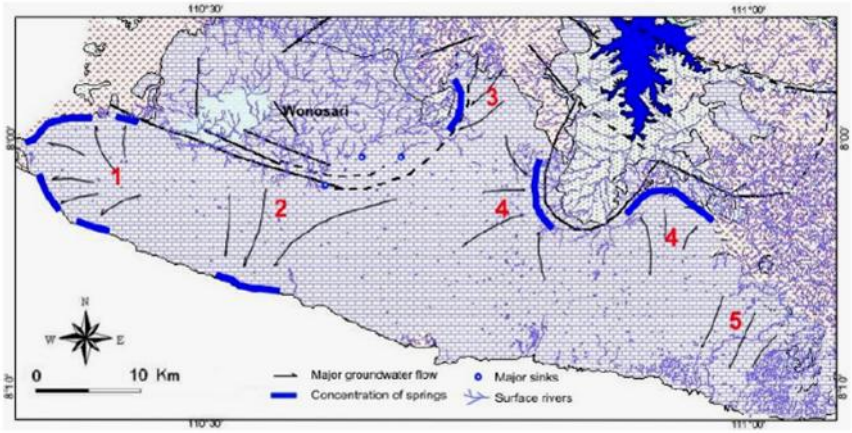


Figure 2.3.3 Map of the Hydrogeological Unit in Gunungkidul Karst

Source: Haryono (2000)

Table 2.3.2 Characteristics of the Hydrogeological Unit in Gunungkidul Karst

Zone	Hydrogeological Unit	Characteristics
1	Panggang sub-system	Overlying volcaniclastic sedimentary rocks, bounded by an escarpment along the western part. Springs are most likely developed in the northern and western part, whilst the likelihood of springs in the southern part is lower.
2	Bribin-Baron-Ngobaran sub-system	The most explored and comprehensively studied, the recharge area of this unit covers both the karst regime and volcaniclastic sedimentary rock, distinctly characterised by the emergence of underground rivers on the coastline facing the Indian Ocean.
3	Ponjong sub-system	This unit is not connected to the coastal boundary. The groundwater flows towards the eastern part of Wonosari Basin, meeting with the fault scarp with north-south orientation, from which several large springs emerge.
4	Pracimantoro-Giritontro sub-system	A bedded limestone unit where the majority of the springs are found in the northern part of the karst boundary (distant from the coastal zone). Groundwater flows northward to the Baturetno Basin.
5	Donorojo-Pringkuku sub-system	Structurally controlled by a joint or fault system, this unit has an immense potential for groundwater for local utilisation. The groundwater table gradually deepens as it goes southward, which is the core of the karst region.

Source: Haryono (2000)

As mentioned above, the hydrogeological units contribute to the appearance and pattern of the water resources in the region. Generally, Gunungkidul water resources are characterised by a significant proportion of groundwater within the limestone aquifer systems that accommodate groundwater accumulation, largely manifested in underground rivers, as affirmed by Yogafanny & Legono (2021). Although the landform restricts the availability of surface water, there are a few possibilities of groundwater emergence at the surface via natural springs, subject to geological properties, hydrological dynamics, and seasonal variabilities.

2.4 Coastal Typology in Gunungkidul Karst

Gunungkidul karst extends as far south as the coastal zone of Gunungkidul, significantly influencing its karst morphology. The interaction between marine and karst environments constructs distinctive coastal landforms. Coastal landforms in Gunungkidul

vary due to their exposure to terrestrial and marine forces, as well as anthropogenic factors, resulting in various coastal typologies.

The most widely adopted and timely relevant theory of coastal typology comes from Francis Shepard in 1973, for its detailed classification and inclusive approach (USACE, 1995). Shepard classifies coastal typology into two main categories: 1) primary coasts (configured by terrestrial processes) and 2) secondary coasts (formed by marine agents, including marine organisms, which may or may not be developed from primary coasts). Table 2.4.1 summarises the classification of each category.

Table 2.4.1 Coastal Typology Classification

Category	Typology	Features
Primary Coasts	Land erosion coasts	Formed by subaerial erosion and partly retreating due to sea level rise during the postglacial era or inundation from a melting ice mass in a coastal valley.
	Subaerial deposition coasts	Following the slowing of sea level rise in the postglacial age, more river deposition takes place, extending the coastline.
	Volcanic coasts	Developed due to strong influence from volcanism or products of volcanic eruption.
	Shaped by diastrophic movements coasts	Structurally shaped coasts, mainly formed by the fault-joint system or sedimentary extrusions.
	Ice coasts	Glaciers development that extends to the coastline.
Secondary Coasts	Wave erosion coasts	Submerging coasts, influenced by eroded cliffs and wave erosion.
	Marine deposition coasts	Emerging coasts as a result of constant waves and currents-driven accretion.
	Coasts built by organisms	Built by either coral reefs, mangrove, or marsh grass.

Source: Shepard (1973) in USACE (1995)

The extensive Gunungkidul karst landscape converges with the dynamics of marine processes in the Indian Ocean, shaping various coastal typologies. Marfai et al. (2013) used Shepard's classification to distinguish the coastal typologies in Gunungkidul by examining their evolution according to geological history as follows: 1) Initially, as part of Gunungsewu karst, the Gunungkidul karst formation was primarily triggered by tectonic movement that

uplifted the undersea limestone, developing a structurally shaped coast as the earliest coast typology; 2) Marine influence began to dominate once the tectonic uplift became inactive, beginning to form secondary coasts: wave erosion coast, and concurrently shaping subaerial deposition coast; 3) Coastal hydrodynamics also forms marine deposition coast, especially in concave coasts.

Regarding the distinct features of each coast typology, primary and secondary coasts face various water resource challenges that could disrupt local activities, including tourism. For instance, volcanic coasts (primary coasts) such as those in the Canary Islands, a well-known coastal tourist destination in Spain, may encounter issues with freshwater availability. Due to the presence of a dyke, a volcanic geological structure that controls the interface gradient between saltwater and freshwater, the islands may experience salinisation depending on the saltwater influence on inland freshwater (Marazuela et al., 2023). The East African coastal aquifer is considered young and unstable, which might trigger potential salinisation of local aquifers (Comte et al., 2016). In Bangladesh, the delta coast of the Ganges-Brahmaputra has experienced severe freshwater shortages and water contamination in surface and groundwater resources, driven by geomorphic dynamics and anthropogenic interferences, thereby worsening water scarcity (Bricheno et al., 2021; Murshed & Kaluarachchi, 2018; Paszkowski et al., 2021). In contrast, secondary coasts, such as coasts built by organisms, including small island nations, are susceptible to water crises owing to limited freshwater storage (Hernández-Delgado, 2024; Korten, 2023; Welsh & Bowleg, 2022). Marine-dominant wave erosion coasts are at greater risk of intense erosion, implying increased vulnerability to SLR and salinisation. Climate change-induced SLR and shifting wave patterns exacerbate erosion, actively altering coastlines (Griggs et al., 2019). Meanwhile, tourism development often occurs on marine deposition coasts (Purnomo et al., 2016). This heightens water stress due to excessive withdrawal and pollution from tourist activities, degrading water quality and disturbing freshwater supplies. Besides the impact on water resources, the geography and geomorphology of each coast also pose internal and external threats.

The diverse coastal typology in the region embeds both natural resources and hazards. Coastal Gunungkidul has become a source of income for locals, with many relying on coastal tourism as their livelihood, supported by the local government, which prioritises this sector's economic development. As previously mentioned, some hydrogeological sub-systems feature coastward groundwater flow, supporting tourism activities in coastal areas, despite high water usage. Many coastal tourist destinations have been established, and this trend is expected to continue.

Gössling & Hall (2017) forecast that the water resource in most countries will decline due to over-extraction and climate change-driven shifts in rainfall patterns. As climate change intensifies, the region faces natural and human-made threats. Widura & Mardiatno (2022) highlighted that coastal Gunungkidul is considered a moderate to highly vulnerable zone because of its coastal typology, tidal wave activity, and potential SLR. SLR threatens the area, exposing it to heightened hydro-climatological hazards such as cyclones, storm surges, and tidal floods, which can damage infrastructure and natural environments (Mustika et al., 2024). The variety of coastal typologies and karst landforms in Gunungkidul complicates groundwater management. Depending on geological setting and hydraulic head balances, long-term SLR exposure may lead to increased saltwater intrusion, potentially worsening salinisation, particularly in coastal and low-lying areas with shallow aquifers (Langevin & Zygnerski, 2013; Yu et al., 2016). In the coastal karst of Gunungkidul, SLR signals the risk of saltwater intrusion where groundwater flows converge and springs emerge. This risk could increase as coastal tourism grows, which raises water demand and intensifies groundwater extraction, especially along beaches with highly permeable materials (Pemerintah Kabupaten Gunungkidul, 2007).

2.5 Water Resources from the Lens of Tourism

For several reasons, tourism has rapidly evolved into one of the most influential economic sectors in the global economy over the past two decades, affecting both more economically developed countries (MEDCs) and less economically developed countries (LEDCs) (Pjanić, 2019). Tourism sectors foster positive economic growth by generating revenues, jobs, trades, and investment (Athanasopoulou, 2013; Cimbaljević et al., 2025). Wang & Tziamalis (2023) argue that tourism equitably redistributes wealth and mobilises private capital from developed nations to developing nations. The substantial economic growth driven by tourism has led European Union (EU-27) and Association of Southeast Asian Nations (ASEAN) to recognise tourism as a strategic economic sector in their region; with the EU-27 consistently ranked as the most popular tourist destination, receiving over 400 million international travellers, whilst ASEAN recorded 85 million international tourists, placing it fifth amongst the world's major tourism regions (Athanasopoulou, 2013). Furthermore, the presence of tourism and travel companies fosters greater prosperity through extensive employment, benefiting the most vulnerable populations (Castilho & Fuinhas, 2025).

Tourism sectors also influence political, social-cultural, and environmental advancement (Tabash, 2017). For instance, a tourism development programme can improve environmental life quality by enhancing access to clean water and sanitation (Elgin & Elveren, 2024). Conversely, tourism development can have negative environmental impacts, notably on water resources. A study by the United Nations Environment Programme (UNEP) in 2014, cited in Lemma (2014), found that water exploitation mainly occurs in large tourism enterprises and in water-scarce regions with extreme consumption patterns, where tourists' water use doubles that of their household consumption.

Researchers and practitioners have increasingly focused on tourism activities, regarding their expanding interplay with other sectors, particularly in water allocation and management. Swarbooke (2023) asserts that the tourism industry has diverted water resources from local residents to their facilities (hotels and resorts), despite awareness that most tourist destinations are situated in a water-stress region, such as Southern Europe or the Mediterranean. Similarly, Page et al. (2014) agree that current water allocation has been politically controlled and prioritised for the tourism sector, often trading off residents' water supplies for tourism development. This issue is compounded by inconsistent practices in responsible water management and superficial stakeholder engagement, resulting in inadequate environmental measures during decision-making and neglecting socio-economic benefits (Warnken et al., 2001). Whilst most popular tourist destinations heavily depend on a reliable water supply to sustain and expand their operations, this sector can become a major water consumer that threatens water reliability, causing negative repercussions across economic, social, and environmental dimensions (Hadjikakou et al., 2013). This situation underscores both the vulnerability of the tourism sector and its potential to undermine water sustainability. Unfortunately, water consumption in tourism remains underrepresented in research and statistical analysis, resulting in water mismanagement that may exacerbate water crises in certain contexts. To illustrate, the global water use attributed to tourism accounts for less than one per cent, yet this figure reflect only direct consumption and does not sufficiently account for indirect water footprint such as those from building development, food production, and energy generation; leaving this broader aspect remains less understood and reducing awareness of tourism's substantial role as a regional major water user and competitor, which can intensify local water shortages, especially in water-scarce tourist destinations (Gössling et al., 2012).

Water serves as a vital resource for direct consumption in tourist accommodation and essentially supports landscaping and various recreational activities (Ricart et al., 2024).

However, tourism potentially introduces a wide range of water issues, especially in regions with water difficulties and booming visitor numbers. Tackling water issues within tourism poses challenges for stakeholders, given the continuous changes within the tourist destinations. One critical aspect for stakeholders to consider when addressing existing disputes is understanding the linkage between the state of tourism areas and water management. In light of environmental resource deterioration due to increasing tourism appeal, Butler (1980) introduced the tourism area life cycle (TALC) as a framework to understand the developmental sequence of tourist areas and their possible future trajectories, aiding resource planning and management in tourist destinations. This concept emphasises the economic, socio-cultural, and environmental carrying capacities, which depend on the popularity of the tourism areas, determined by the level of tourism investment and the growth rate of tourists (Butler, 1980, 2011). Similarly, this theory suggests that tourist destinations follow an evolutionary pattern driven by demand and supply dynamics in tourism, offering a prospective tool for formulating and adapting strategies at each stage (Tooman, 1997). Figure 2.4.1 presents the TALC model, illustrating the hypothetical cycle of a tourism area, beginning with exploration, where no dedicated infrastructure exists; progressing through stages, and inclining towards multiple options from rejuvenation to decline, depending on the market, natural capital, and infrastructural changes (Butler, 1980, 2011; Tooman, 1997).

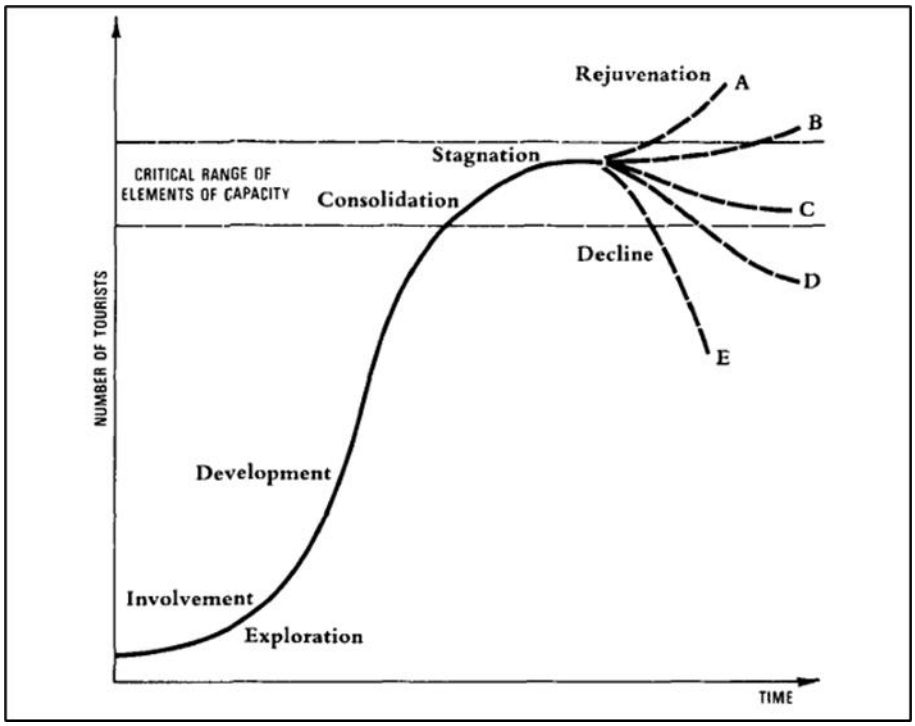


Figure 2.4.1 Butler's Tourist Area Life Cycle Curve

Source: Butler (1980)

The carrying capacity of tourism water resources represents both an important parameter and a constraint factor in tourism development research (Qiuyun et al., 2011), for which the TALC model can help identify water resource challenges across different states of tourism areas. This cyclical nature of tourist destinations indicates existing water issues at each stage and influences water management strategies. For instance, from 1889 to 1912, tourism in Cairns, Australia, was at the exploration stage, with few facilities due to unfavourable market conditions, as tourism had insignificant contributions to the social and economic life of the Cairns population; yet later in the development stage, more accommodations and facilities appeared (Berry, 2000). Likewise, Tioman Island in Malaysia, from 1890 to 1969, was also in the exploration stage, during which tourist infrastructure was absent, thus all visitors relied on locals' private facilities, including toilets and kitchens, fostering close interactions between tourists and dwellers (Omar et al., 2015). At this stage, there were no public infrastructures, including water supply systems.

The need for such systems grew with the increasing number of travellers, which is evident in later stages, such as development, consolidation, and stagnation. This situation is well exemplified by Costa Brava, a renowned Mediterranean coastal destination, where the water supply governance was initially managed solely by public administrators; plans to privatise the entire potable water system emerged after tourism boomed (Pavón et al., 2018). Similarly, Bali, Indonesia, facing overtourism in recent years, has entered the stagnation stage of the TALC model, where pollution and environmental degradation are more apparent (Sari et al., 2024). The large influx of tourists has raised concerns about water scarcity, despite improvements in the region's capacity to supply water for both tourism and local needs (Yamamoto et al., 2021). Culturally, the imbalance of economic power and governance within the tourism industry has disproportionately affected water use, access, and allocation, threatening the water resources for Balinese religious customs (Saraswaty, 2024).

Apart from the state of tourist destinations, a country's level of economic development influences water management and tourism. Developed and developing countries face contrasting challenges in navigating water disparities driven by tourism. Factors such as economic capacity, governance profile, public awareness and tourism attitudes, and environmental conditions shape challenges and guide strategies to improve water resource management amidst booming tourism. These factors vary geographically and are most pronounced in water-scarce, climate-sensitive destinations.

The economic gap between developed and developing nations reflects their differing abilities to manage water for tourism. Developed countries have greater resources, higher

investments, more robust regulatory frameworks, advanced infrastructures, and technological access to cope with rapid tourism growth and related water issues (Lehmann, 2008). Some major industrialised countries, such as the USA, Italy, Spain, and certain island states, can invest more in advanced water management technologies, such as water recycling and desalination, to secure water supplies for tourism (Gössling & Hall, 2017; Lehmann, 2008). Well-funded regions can establish comprehensive water stewardship programmes involving public-private sector partnerships and community participation, which are crucial for improving water efficiency in tourism (Refaat, 2015). These nations may also reduce water intensity through environmentally sustainable technological advancements driven by increasing tourism water demand (Sun & Hsu, 2019). Conversely, developing countries often lack the financial means to adopt such strategies. Ideally, investments would demonstrate tourism's commitment to sustainable infrastructure and reducing water inequality (Sinha et al., 2020). Meanwhile, in developing nations, local communities frequently compete for water, experiencing disproportionate use, allocation, and access due to unregulated and excessive water extraction by tourism establishments to meet rising demands, often at their expense (Cole & Ferguson, 2015). This trend is evident in Bali, where tourism growth exacerbates existing water shortages, albeit with improvements to household water systems (Yamamoto et al., 2021).

Water and tourism governance are interconnected, with tourism exerting both positive and negative impacts on water resources (Geng et al., 2020). Effective governance is needed to address environmental and societal concerns stemming from tourism activities (Ricart et al., 2024). Governance structure critically shapes pathways and responses to water-tourism issues. Developed countries have robust regulatory frameworks that enable an integrated practice of sustainable water use in tourist destinations through well-coordinated stakeholder engagement and comprehensive management strategies. For instance, in 2013, the EU institutions designed the European Tourism Indicator System (ETIS), initiated by the United Nations World Tourism Organisation (UNWTO) and the Global Sustainable Tourism Council (GSTC), as an instrument of management, monitoring, and measurement of sustainable tourism performance (Drius et al., 2022). Costa Rica has pioneered sustainable tourism through their world-leading ecotourism business, establishing an integrated decentralised governance system called *Sistema Nacional de Areas de Conservación* (SINAC) under the Ministry of Environment and Energy (MINAE) since 1998, to authorise, manage, and protect forestry and water resources (Miller, 2015). These cases exemplify that strong frameworks facilitate inclusive tourism policies that address water resource sectors.

Developing countries often struggle to meet diverse sectoral interests. The roles of each sector may merely involve managing specific issues, whilst they must also navigate conflicting objectives and administrative disputes (Shah, 2023). In Indonesia, ineffective bureaucracy and poor collaboration amongst stakeholders have hindered coastal tourism management, urgently calling for an update and synchronisation of regulatory frameworks across multiple stakeholders (Hengky, 2023). Likewise, inadequate planning, governance, and decision-making, coupled with rising water demand from tourism, have exacerbated the water, sanitation, and hygiene (WASH) situation in Labuan Bajo, Indonesia, intensifying local water scarcity (Cole, 2017 in Dwipayanti et al., 2022). The local water utility has struggled to resolve chronic water issues in certain areas, including service quality, regularity of supply, pricing, and network expansion (Dwipayanti et al., 2022).

Public awareness and tourism attitudes in tourist destinations also vary considerably between developed and developing countries. Limited knowledge often leads to irresponsible water consumption behaviour in tourist destinations, especially in developing countries. According to Page et al. (2014), tourists are generally unaware of their water footprint and consistently underestimate the magnitude of their impact. Tian et al. (2015) suggest that increasing awareness is a key strategy to alleviate water crises. Environmental conditions further influence how countries resolve water demand and supply issues in tourism. Developed regions may diligently engage in proactive climate adaptation and resilience measures that focus on water resource conservation to endure the water scarcity, although many tourism stakeholders cannot fully comprehend the indirect costs of such strategies (Gössling et al., 2012).

2.6 Water Service in Coastal Tourism System

Most water-based tourism activities are still concentrated in the neritic province (a part of coastal areas), despite advancements in the independence and safety of marine-based tourism industries (Orams & Lück, 2013). Coastal areas host the majority of accommodations and tourist arrivals (Rico-Amoros et al., 2009), promoting the growth of coastal tourism. Coastal tourism is viewed as a dynamic system where interactions amongst people occur in destinations, whether in small communities, idyllic, sophisticated resorts, or vibrant cosmopolitan areas (Miller & Auyong, 1996 in Anirban, 2020). Coastal landscapes offer appealing values that have made them popular tourist spots and vital sources of income (Anirban, 2020). Over 60% of Europeans prefer beach vacations, and coastal tourism generates more than 80% of the overall US tourism revenue (Nicholls, 2014). Likewise,

coastal tourism has become one of the fastest-growing subsectors in the industry, providing significant income for countries in the Mediterranean (Europe), as well as Asia-Pacific countries such as Indonesia, Malaysia, and the Philippines (Anirban, 2020).

Given its importance and scale, coastal tourism raises complex water issues. Water is an essential resource for multiple purposes, including recreation, sanitation, and culinary processes in coastal tourism, highlighting the water-intensive nature (Arabadzhyan et al., 2021). With rising tourist arrivals, a sufficient clean water supply must be maintained at all times in coastal destinations, whilst also addressing the potential water-related risks to industry sustainability (Sustainable Hospitality Alliance, 2013). However, the popularity of coastal tourism can also induce water stress for downstream communities. Coastal communities face major challenges in achieving sustainable development for safe and clean water supplies, especially in a more perturbed climate and human environment (Chen et al., 2021).

The Mediterranean coast has long been renowned for its high-traffic tourist areas, but water resource issues now overshadow this reputation. Water resources are disproportionately distributed, with the northern Mediterranean holding most of the water resources, whilst the south and east face water scarcity, along with other constraints and potential disputes amongst different users in the future, including increasing water demand for tourism and agriculture, higher flood risks in urbanised areas, climate change, and overexploitation (Fader et al., 2020). Freshwater in the region includes surface water and aquifers in transboundary river basins. The northern Mediterranean's river basins contribute 71% of the annual discharge into the Mediterranean Sea, whereas the southern and eastern regions account for 17% and 12% respectively (Struglia et al., 2004 in Fader et al., 2020). The diversity of groundwater resources depends on the types of aquifers; karstic carbonated aquifers and alluvial aquifers are amongst the most common, whilst sedimentary aquifers, despite their abundance, are non-renewable (Fader et al., 2020). Over 90% of groundwater comes from the northern Mediterranean, whereas the combined recharge in the southern and eastern regions makes up less than 10% of the overall Mediterranean groundwater (Fader et al., 2020).

The Mediterranean region demonstrates extensive use of freshwater for coastal tourism, relying on multiple water sources to meet demand. Inhabitants along the Adriatic coast have traditionally relied on rainwater harvesting during the rainy season or utilised coastal minor karst springs (Tedeschi, 1986). In Croatia (northern Mediterranean), the Boljkovac pumping station extracts water from the coastal karst aquifer within the Bokanjac-Poličnik catchments of Dinaric Karst to serve local coastal tourism near the Adriatic Sea (Biondić et al., 2022).

Similarly, in arid and semi-arid regions such as Tunisia (southern Mediterranean), the coastal aquifer is a vital source of water, with fresh groundwater drawn from the Jorf aquifer (Agoubi et al., 2013). Despite its importance across both parts of the Mediterranean, the stability of this water source faces increasing risks from climate change.

Seawater intrusion or salinisation of freshwater aquifers has been recognised as a growing threat in the Mediterranean (Mastrocicco & Colombani, 2021). Salinisation can compromise water quality and reduce availability in coastal aquifers, intensifying competition between coastal communities and tourists. This issue worsens as tourist accommodations often require more water from municipal utilities for recreational facilities, further straining local supplies (Morote et al., 2016). Salinisation and a mismatch between water demand and supply have prompted some regions of the Mediterranean to adopt advanced measures to secure water resources. Desalination is one of the most prominent non-conventional water supply technologies used along the Mediterranean coast, especially in drought-prone areas and where sources are contaminated by saltwater. In 2005, the Mediterranean Spain experienced an extreme drought, prompting the launch of Spain's early desalination plants (Garcia-Castello et al., 2007). In Egypt, water is produced by desalinating either brackish water or seawater, alongside supplies delivered by the water trucks or pipelines from the Nile River (Refaat, 2015). In the coming years, technologies like desalination may collectively drive a significant shift in water governance across the Mediterranean. Since 2005, the *Acciones para la Gestión y el Uso del Agua* (A.G.U.A.) programme, supported by the Spanish Government, has established numerous desalination facilities, as government policies and priorities have evolved (Arahuetes & Villar, 2017). Some countries now depend more on desalination and treated water than on over-stressed local reservoirs (Hof & Schmitt, 2011).

On the one hand, the ongoing practice of water governance in parts of the Mediterranean has led to unsolved and mismanaged water demand-supply situations. Water authorities often respond to demand with supply-focused measures, prioritising providing more water for economic purposes, such as tourism, rather than introducing strategies for sustainable and efficient water use (de Stefano, 2004). Nonetheless, the proliferating tourism is believed to be a countermeasure to water scarcity, as heightened attention to desalination, water recycling, and water storage capacity enhancement provides a wider perspective on water security for the future (Lehmann, 2008). Despite the environmental and energetic problems that may arise from such cutting-edge technologies, the region has demonstrated stronger resilience to various water stress situations, including droughts (Baños et al., 2019).

On the other hand, the landscape of water management in coastal areas involves not only the technology used but also the stakeholders whose roles are vital to ensuring equitable and efficient distribution. For instance, Costa Brava in Spain, whose water supply system evolved from a simple water-fetching society in the early 20th century, going through the 1950s' tourism boom that forced to potable water network expansion, to a complex heterogeneous water providers operated by companies, with private holding 71.42%, mixed enterprise public-private 23.92%, and public 4.66% ownership today (Pavón et al., 2018). Over 80% of municipalities in Mediterranean Spain are served by private providers, exhibiting non-public dominance (Villar & Arahuetes, 2017).

In Indonesia's Bali, one of the most visited tropical coastal destinations, the water sector has been reliant on local sources since the New Order regime (President Suharto's administration from 1966 to 1998), which supported mass tourism development (Tarigan et al., 2013). The island's diverse water sources, including springs, groundwater wells, and river flows, are heavily used to meet tourism demand. According to Cole (2012) as cited in Tarigan et al. (2013), tourism consumes approximately 65% of Bali's water supply. In Gianyar Regency, water comes from spring tap water, groundwater wells, and downstream river flows (Parwita et al., 2023), whilst in Tabanan Regency, supply is managed primarily by the Regional Drinking Water Utility (PDAM) and the Community-based Drinking Water and Sanitation Programme (PAMSIMAS) (Andayani et al., 2023). PDAM also manages the water supply in Nusa Penida Island. The island's karst landscape limits perennial streams but provides vast groundwater and karst springs (Sudipa et al., 2020). Considering the increasing population and tourists in Southern Bali, the government has undertaken projects, such as Titab reservoir, Tamblang reservoir, Petanu and Penet long storages, and the underway Sidan reservoir, to alleviate water stress (Parwita et al., 2023).

The island's tourism has expanded, threatening water sustainability and provoking social conflicts due to imbalanced water allocation given to agricultural sectors. The current water governance leans towards supporting tourism massively, pressuring water supplies and creating tension with the community. Although the island is known for its deeply rooted local wisdom, namely *Tri Hita Kirana*, the water governance practice has not succeeded in contributing to the reduction of water-related risks, including ones prompted by tourism (Hornbacher, 2021). The existing governance places less appreciation on the entrenched value of *Tri Hita Karana*, and is not inclusive, as the cultural roles of the local community are not strongly involved, hindering the realisation of sustainable water management (Pradipta & Putri, 2024).

The island has witnessed water disputes due to massive tourism since Indonesia's independence. The market domination of tourism sectors includes private enterprises producing bottled drinking water, and PDAM prevailed control over the water supply of an agricultural society where water distribution was in deficit, despite an adequate water supply (Strauß, 2011). A unilateral ownership claim of the Gembrong spring in the Yeh Ho upstream catchment, an irrigation source of 6,000-ish hectares of Balinese rice fields, was issued by PDAM, reinforced by the central government, to provide more water access to a non-agricultural-based economy, especially the urban community and hospitality industry in Southern Bali (Tarigan et al., 2013). Hornbacher (2021) highlights that water crises in Bali, an island rich in its water springs, are alarming and trigger social friction between Balinese peasants and the urban community in tourism cosmopolitan areas due to declining water availability for rice fields. Not only are conflicts prompted by water providers, but tensions also surface amongst the local government. Pradipta & Putri (2024) conducted stakeholder mapping and found that water resource disputes between Badung and Tabanan Regency in Southern Bali have prolonged. The water availability situation worsens because of coastal tourism expansion, stimulating excessive water extraction and seawater intrusion, as well as causing many streams to dry up, whilst groundwater tables drop irreversibly sometimes (Hornbacher, 2021).

Both the Mediterranean and Bali illustrate how coastal tourism can either drive or be impacted by water scarcity. The Mediterranean experiences erratic precipitation, exposing it to natural aridity and water scarcity, which could worsen if coupled with the unprecedented impact of climate change. Tourism has transformed and strengthened water governance in the region, where stakeholders are committed to boosting the capacity of the existing water supply for tourist destinations. Otherwise, Bali's rapid tourism growth directly and indirectly stimulated water supply issues and social tensions amongst different users. Moreover, water governance fails to uphold local wisdom and inclusively involve water users in the policymaking phase, opening the possibility of water disputes.

2.7 Water Service in Coastal Karst of Gunungkidul

The water resources in Gunungkidul are diverse and intricate, comprising 37 main surface rivers and 286 small lakes, most of which run dry during the dry season, 75,845 water wells with varying depths, and numerous water springs that have not been utilised by the locals, mostly replaced by the availability of water service from either PDAM or Rural Drinking Water Provision System (SPAMDes) (Dinas Lingkungan Hidup Kabupaten

Gunungkidul, 2021). Nestmann et al. (2009), cited by Fuchs et al. (2015) highlight that rural communities have used water wells, surface water, harvested rainwater, or water delivered by PDAM. Since the establishment of PDAM's distribution network, the reliance on small lakes to supply clean water in Gunungkidul has decreased, and they no longer serve as a drinking water source, except for bathing, animal husbandry, and aquaculture (Cahyadi, 2017).

The dry landscape of Gunungkidul highlights the vulnerability of the region to climate-induced challenges, which often put it under water-sensitive strains. People in the region used to have a lot of dolines filled with water available for meeting their needs. Around 90% of the water supply was supported by dolines before the 1990s (Haryono et al., 2009 in Widyastuti & Haryono, 2016). After this period, merely 30% of dolines have remained functional for those who could not access the groundwater because of the deep water table (Widyastuti & Haryono, 2016). The physical features have unfavourably put Gunungkidul in a state of deficient surface water resources.

Due to its natural environment, the water resources in Gunungkidul are predominantly characterised by significant contributions from groundwater, especially underground rivers. Currently, the majority of the population utilise groundwater to supply their daily household water consumption, whilst some practice rainwater harvesting. However, underground rivers are the only feasible water sources throughout the year, unlike rainwater, which tends to vary more seasonally (Sidauruk et al., 2017). Within the existing water system, some parts of Gunungkidul have consistently received water supply from PDAM, which abstracts and distributes water from the potential underground rivers throughout its pipelines. PDAM is a state-owned water utility appointed by the corresponding government to regulate and manage the quantity and quality of water sources and their allocation to supply drinking water (Irshabdillah & Widyastuti, 2020). Unfortunately, this service has yet to cover the entire region despite its good connectivity due to socio-economic constraints faced by certain groups in accessing water (Dinas Lingkungan Hidup Kabupaten Gunungkidul, 2021; Lantarsih et al., 2023). Furthermore, the company has not fully maximised the potential of underground rivers in Gunungkidul. Baron, Bribin, Ngobaran, and Seropan are amongst underground rivers that have supplied potable water, whereas 5,050 litres per second of discharge from Grubug, Toto, and Sumurup underground rivers have yet to be utilised by PDAM (Sarminingsih et al., 2021).

Topographical barriers have created substantial obstacles for water provision in Gunungkidul. PDAM Tirta Handayani is the largest regional stakeholder in providing clean and safe water to the population. However, some isolated or inaccessible areas in the region

have not fully received water from the company. Alternatively, other water providers have been established in the region as a supplement to the current system. The water supplies are also supported by SPAMDes and PAMSIMAS, two entities that share similar purposes to deliver water to the community (Nurmalia, 2019).

PDAM Tirta Handayani is a regionally-owned enterprise engaged in the drinking water supply services, as well as aiming to create more local own-source revenue to improve people's prosperity (Regional Law of Gunungkidul Regency Number 9 of 2019 on Tirta Handayani Regional Drinking Water Company, 2019). The utility sources raw water from five major underground rivers in Gunungkidul: Baron, Bribin 1, Bribin 2, Ngobaran, and Seropan (Cahyadi, 2017). Baron and Ngobaran underground rivers are two important water sources in the coastal Gunungkidul (Irshabdillah & Widyastuti, 2020). Baron-Bribin underground river system flows southwestwardly, and its outlet reemerges at Baron Beach, whilst the waterflow of Ngobaran underground river system reappears at Ngobaran Beach (Nuraini, 2012). The Baron unit was considered the first infrastructure and system for pumping out groundwater from its outlet in the coastal area, with technical assistance from the Japanese Government (Nugroho et al., 2020). As some resurgences come out at the beach, coastal areas may possess abundant water resources. This company operates daily pumping, producing potable water and generating its income from water delivery fees that customers pay, for which the tariff is determined by considering full cost recovery for continuous operation and maintenance (Husain et al., 2022). With the current business model, PDAM Tirta Handayani has expanded the distribution network to almost cover its entire service area, despite the lower capability to optimise the performance of existing pipelines (Sari, 2009).

SPAMDes is a drinking water supply system for rural communities, whose infrastructure, including pipelines, treatment facilities, and water tanks, is designed based on assessments of local water demand and material availability (Barid et al., 2025). SPAMDes has its own management system and maintenance procedure since the rural community groups are directly involved in the project (Lutfia et al., 2024). The development of SPAMDes requires funding support, which can be acquired from either the government (PAMSIMAS project) or the individual's financial budget (Lutfia et al., 2024). Meanwhile, PAMSIMAS itself is a community-based programme which plays a vital role in facilitating the provision of adequate potable water and sanitation services to enhance access and foster hygiene and healthy rural and peri-urban communities (Praja et al., 2024). PAMSIMAS in Gunungkidul was kicked off in 2017 and has provided clean drinking water to over 18,000 people (Ahdiyana et al., 2025).

The utilisation of multiple water sources through different water delivery service options in Gunungkidul has provided insights into the struggles of the locals and efforts made by related stakeholders to address water insecurity. The region has faced challenges in achieving water accessibility targets, where some populations have not been connected to the water network. Furthermore, this pressure may escalate due to existing competition with the tourism sector and its growing water demand in the future.

2.8 Previous Research

Water service in coastal karst tourism is categorised as an understudied field in Gunungkidul. Gunungkidul constitutes a potential region for tourist attractions as it is bestowed with a long coastline. At the same time, the region has been suffering from episodes of water scarcity in the past. Some scholars pointed out the potential beaches in the Gunungkidul coasts for their tourism activities through a case study approach. Table 2.8.1 briefly outlines past publications that studied coastal tourism in Gunungkidul karst.

Table 2.8.1 Previous Research on Coastal Tourism in Gunungkidul Karst

Author and Year of Publication	Title	Summary
Setiawan (1999)	Hotel di Kawasan Wisata Pantai Krakal Kabupaten Dati II Gunungkidul Daerah Istimewa Yogyakarta: Mengekspresikan Legenda Ratu Pantai Selatan ke dalam Bentuk Arsitektur Hotel	The author observed coastal tourism in the beach complex of Baron-Kukup-Krakal in the Gunungkidul coast. This work studied the design and planning concept by incorporating local wisdom and knowledge. It also encapsulated some discussion related to water sources and infrastructure, where he contextualised the utility concept for the water provision on the beach.
Yuliatmi (2014)	Potensi dan Upaya Pengembangan Obyek Wisata Pantai Sepanjang Desa Kemadang Kecamatan Tanjungsari Kabupaten Gunungkidul	This publication examined the values and efforts involved in developing the Sepanjang Beach tourist attraction. It highlights Sepanjang Beach's untapped potential, along with the infrastructure, tourism promotion, supporting and constraining factors in the development of the beach. The author asserted that the water infrastructure and services were inadequate for meeting the tourist demand.

Nurzaman et al. (2020)	Measuring community resilience against coastal hazards: Case study in Baron Beach, Gunungkidul Regency	The author described the presence of coastal hazards in Baron Beach and how they impact the coastal communities nearby. This article focuses on determining the community resilience against coastal threats. The measurement includes the physical resilience of the water supply, about the dependence of coastal people on the utilisation of the resurgence.
Musmulyadi & Setyowati (2022)	Governabilitas peran Pemerintah Desa Girikarto dalam pengembangan wisata Heha Ocean View	This research emphasised the governability of the government roles in the improvement of the Heha Ocean View tourist site. There are numerous governance problems in managing tourist attractions in the area. It points out the difficulty of water services at the tourist site.
Soviana et al. (2023)	Springs and Tourism Facilities Development in Purwosari, Gunungkidul, Special Region of Yogyakarta, Indonesia	The author assessed the water source alternatives as a response to the surface water source problems in the tourism facilities development on the Purwosari coast. This article stipulates findings of natural spring observation, including their water quality and accessibility to tourism sites. It also elaborates on the potential of each spring for the surrounding tourist attractions by applying spring classification in accordance with the physical data obtained from the spring observations.

2.9 Research Gaps

The former publications pay less attention to the structures of water services, whilst heavily engaging with the tourism aspects. They merely revolve around a small fraction of the coastal Gunungkidul, making this study's focus less representative of the entire coastal tourism zone and considered an understudied research area. As a consequence, there is a lack of comprehensive understanding of the interrelationship between water services and coastal tourism. In addition, the current studies have not proportionately addressed the control of the natural landscape and policy interventions towards the water system of coastal karst tourism.

SECTION III
METHODS AND MATERIALS

3.1 Research Design

3.1.1 Epistemology

This study adopts an interpretivism (constructivism) epistemology, focusing on understanding social reality through individuals' lived experiences, which include subjective interpretations and meanings (Phan et al., 2015). The interpretivist framework is suitable for investigating how physical phenomena and social behaviour shape and influence the water supply system, further highlighting how water for coastal tourism is provided and maintained. This data can be gathered by interviewing various stakeholders, allowing the researcher to discern perceptions and interactions within the water supply system, untangle the complexities of natural and human systems, and gather multiple stakeholders' insights into water-related risks and management in coastal areas (Herman et al., 2014; Rahman & Islam, 2018; Santos et al., 2019; Żywiec et al., 2024). Therefore, employing interviews with multiple stakeholders within this interpretivist epistemology will offer diverse perspectives and enable a comprehensive understanding of the complex realities of water services in coastal tourism.

3.1.2 Methodology and Conceptual Framework

The conceptual framework used in this research is based on social-ecological systems (SESs). Several key concepts related to SESs include multiple scales, multiple levels, and resilience theory, which help explain the two-way feedback loop between human and natural systems (Berkes et al., 2014). From a resilience perspective, SESs encompass complex adaptive systems and core principles involving uncertainty and nonlinear dynamics, as well as the ideas of multiple types of stability and adaptive management strategies, for which resilience is often understood as the capacity to transform with change rather than merely absorbing or adapting to it (Reyers et al., 2018). Uncertainty and complexity within a system necessitate flexible and adaptive management strategies; therefore, policy approaches should undergo ongoing assessment and systematic improvement based on exploring various possibilities within the current system (Petrosillo et al., 2015).

For this study, SESs serve as a crucial foundation to guide the thematic analysis of water service variations in tourist destinations (human system) within the coastal

karst region (natural system). Zhao (2018) emphasises the importance of SESs in this understudied area, as tourism development is unavoidable and causes a range of impacts on ecological systems. The significance of studying SESs in coastal tourism is demonstrated by Smith et al. (2023), who reviewed 100 journal articles, with 44 addressing negative social-ecological challenges linked to coastal tourism development. However, due to the uncertain and complex nature of SESs, coastal tourism does not necessarily lead to negative consequences. Zhao (2018) argues that tourism development will influence the behaviours across all sectors, including water resources, making them more adaptive in an evolving environment.

This research adopts a conceptual framework from Heslinga et al. (2017), which incorporates an SESs approach (Figure 3.1.2.1) to analyse the coastal landscape system and tourism system as a coupled, interconnected system, allowing for a detailed understanding of their interaction and dynamics, as well as exploring implications for advancing tourism planning and governance in multifunctional coastal systems. The chosen framework was suitable for this study due to its practicality and flexibility in explaining the current water service situation in coastal karst tourism in Gunungkidul, including ongoing and potential challenges, as well as in improving comprehension of water issues amidst the local government's plan to expand coastal tourism in the region.

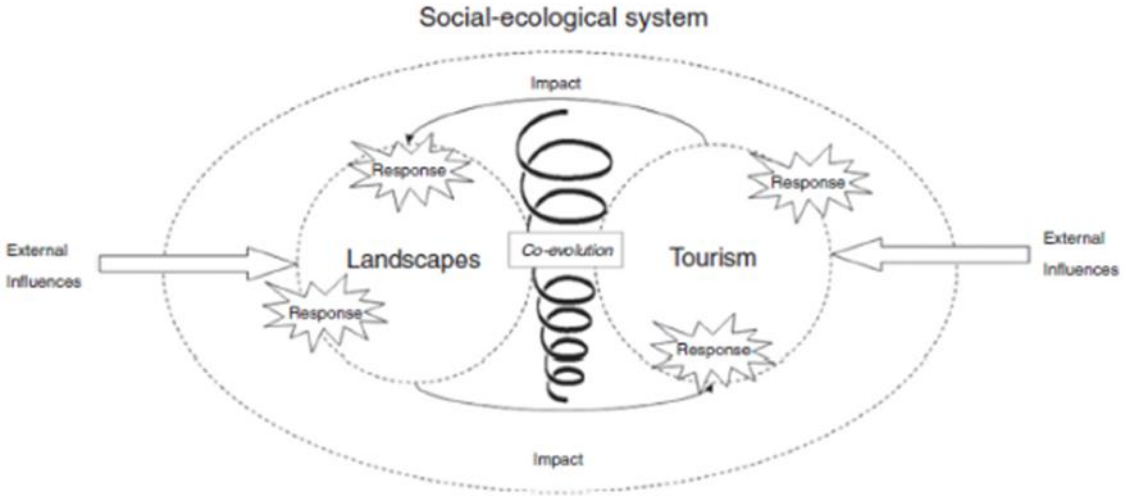


Figure 3.1.2.1 Social-ecological System Between Landscape and Tourism
Source: Heslinga et al. (2017)

The SES model from Heslinga et al. (2017) is conceptualised in the context of coastal tourism in Gunungkidul karst through literature review, employed theories, and research design, resulting in a conceptual framework as depicted in Figure 3.1.2.2. This

framework was conceptualised with both water and tourism-related knowledge. Coastal karst landscapes exhibit the potential of water resources and the associated risks to the coastal community, which are managed by water governance and institutions responsible for regulating water affairs, including the development of water infrastructure to accommodate or address water issues. Water resources and risks are affected by tourist growth and tourism development, which can potentially perturb the natural landscape of tourist destinations. Tourism development is governed by the relevant actors and institutional frameworks within tourism governance, which interact dynamically with water governance, influencing each other and regulating the changing demand and supply of water in tourism areas over time. The response to these changes, reflected in water infrastructure landscapes, determines the types of water services available in the tourism areas.

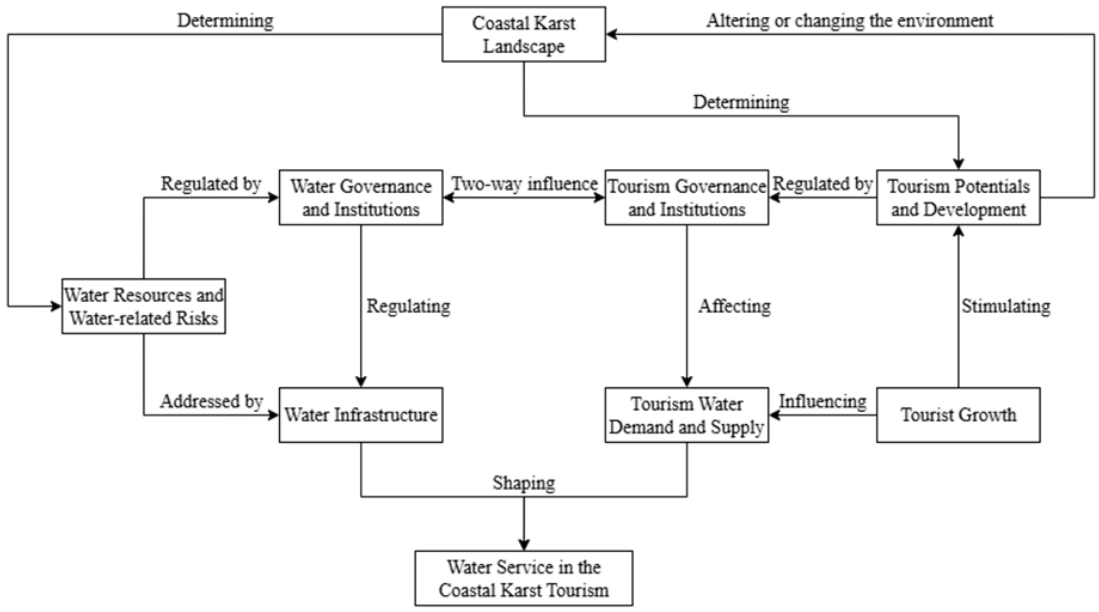


Figure 3.1.2.2 Conceptual Framework

3.1.3 Methods

The study employs qualitative research combining interviews and fieldwork in selected sampling areas. The interviews use open-ended questions designed to gather comprehensive information about the existing water-tourism system, including the current challenges and adaptation strategies, from multiple stakeholders. Diverse perspectives provide a thorough understanding of the research topic. The interview data were examined, selected, and classified through thematic analysis to highlight key areas central to the discussion, supported by the relevant and impactful quotes from the

involved stakeholders (Braun & Clarke, 2013; Naeem et al., 2023). Additionally, significant information from the interviews is visualised with appropriate figures such as graphs, maps, and flowcharts, depending on the context and data type. The interview data serve as a source to understand the interaction between the water sector and the tourism system through the implemented water services in various tourist destinations along the coast of Gunungkidul. This will reveal the diversity and disputes within water service landscapes for tourism purposes in the coastal karst region, and support decision-makers in relevant administrations when addressing these issues. Figure 3.1.3.1 illustrates the flowchart of the overall processes undertaken throughout the research.

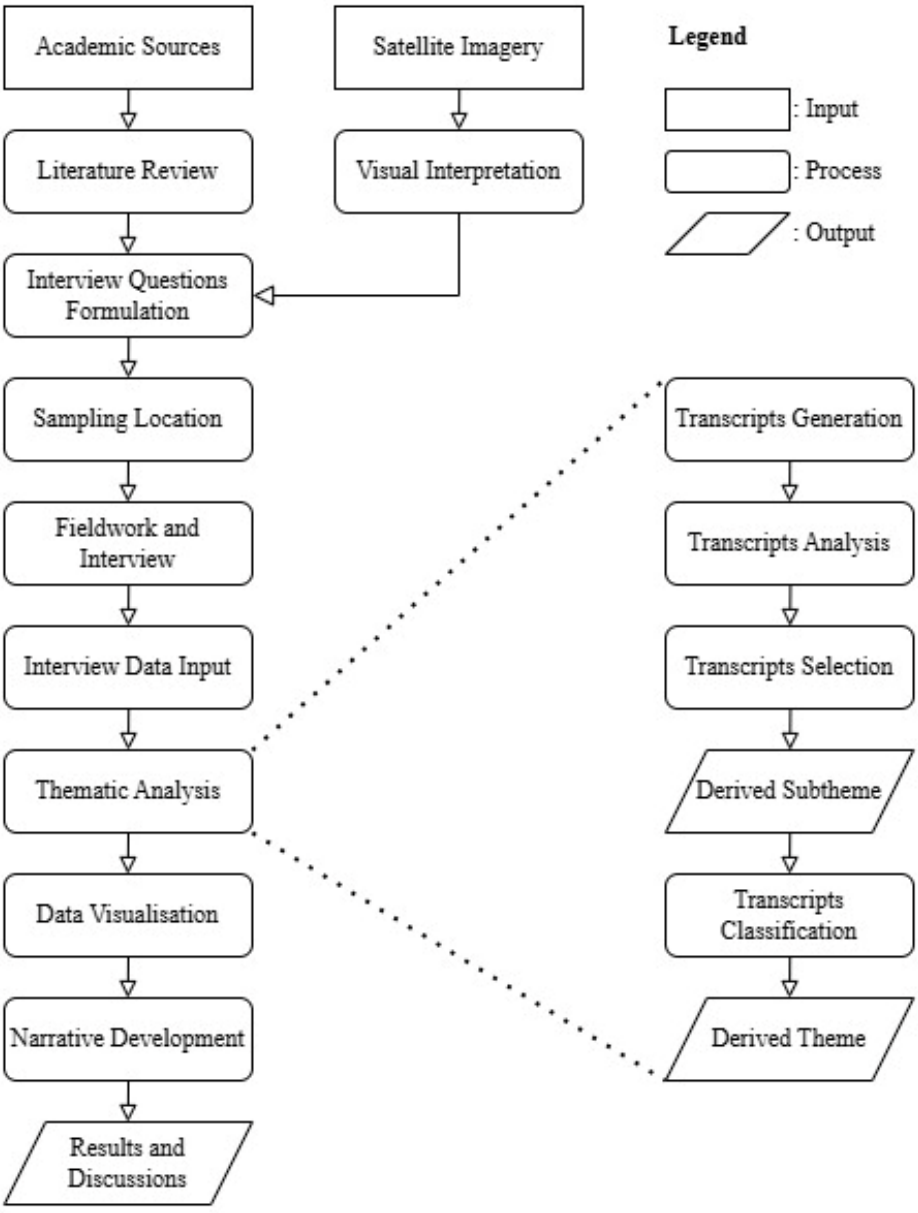


Figure 3.1.3.1 Research Flowchart

3.1.4 Research Tools

The main research tools used in this study are an interview guideline and a computer equipped with the necessary software. The interview guideline is designed to collect primary data through interviews with respondents to answer the research question regarding water services in coastal tourism, and further to analyse the interrelation between water service and coastal tourism in Gunungkidul. Two programs, NVivo and ArcGIS Pro, are utilised to support the data analysis and data visualisation. NVivo is prominently used for thematic analysis, covering data management, processing, and analysis. Meanwhile, some water service data is visualised accordingly, including by ArcGIS Pro when necessary, to illustrate the spatial variance of the phenomenon observed in the study area.

3.2 Study Area

In spite of current staggering water resource problems and the records of drought events, Gunungkidul has become an emerging destination for both domestic and foreign visitors seeking the coastal attractions. The study area encompasses the coastal karst of Gunungkidul, located in the coastal region of the Karst Gunung Sewu (Southern Mountains Karst Global Geopark). The coastal karst of Gunungkidul encompasses six subdistricts: Purwosari, Panggang, Saptosari, Tanjungsari, Tepus, and Girisubo, where many beaches are scattered along their coast (Figure 3.2.1). These coastal tourist attractions are classified according to the Regional Law of Gunungkidul Regency Number 8 of 2020 on Amendment of Regional Law of Gunungkidul Regency Number 3 of 2014 on Masterplan of Gunungkidul Regency Regional Tourism Development of 2014 – 2025 (2020) into their respective zones. Zones 1, 2, 3, and 5 are the development locus of coastal tourism in Gunungkidul. This provision states 39 beaches that have been officially established as coastal tourist destinations, which will be sampled to achieve the research purposes. In this study, the selected data collection areas are based on several criteria, including the coastal characteristics and the development level of coastal tourism. Detailed consideration is provided in the following section.

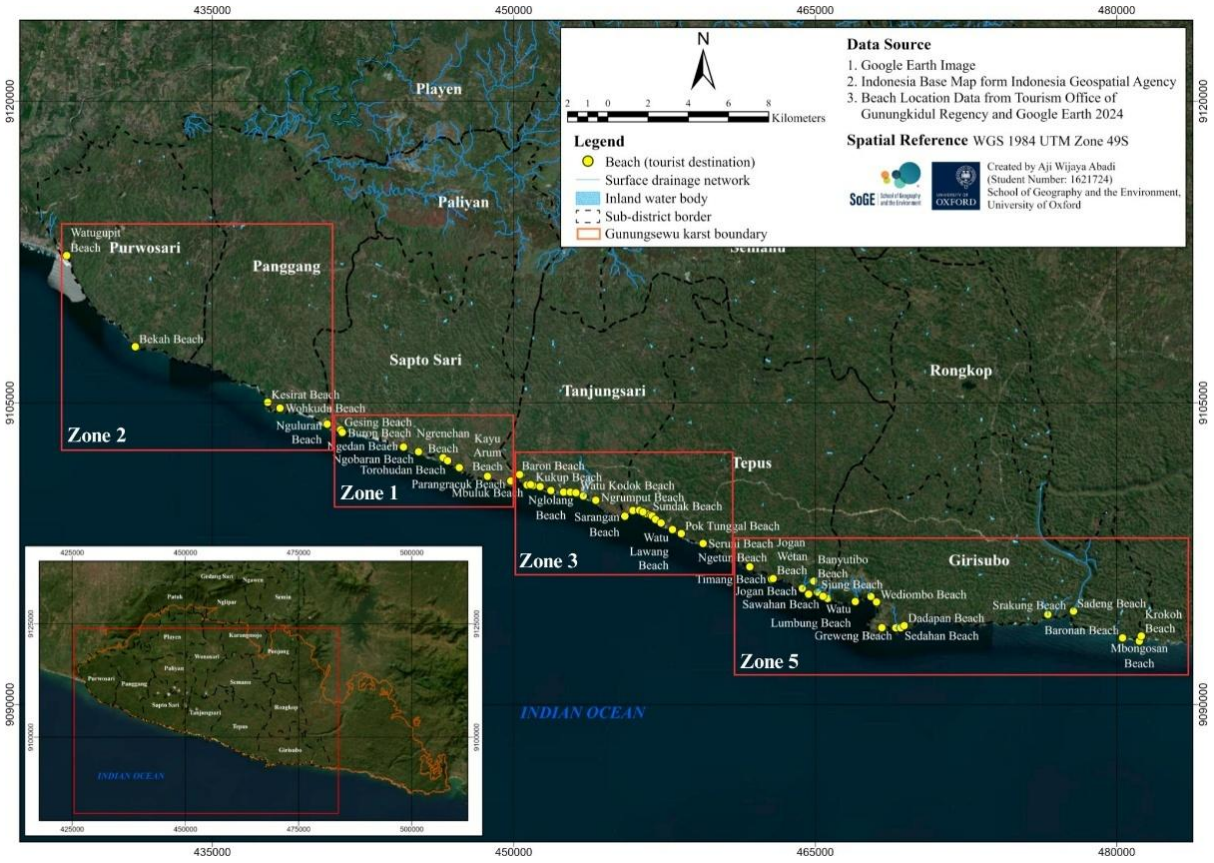


Figure 3.2.1 Study Area

Source: Courtesy of the Author (2025)

3.3 Data Collection

3.3.1 Data Collection Methods

The research utilises a primary qualitative data collection method through interviews for a multistakeholder scope, whilst upholding problem-centred interview principles (Witzel & Reiter, 2013). The interview covers paramount parameters related to water services in the coastal tourism sector, including water supply, water use, as well as water, sanitation, and hygiene (WASH). The interview guideline is divided into sections tailored for each stakeholder group. Data collection comprises two main activities: 1) gathering data from the locals directly engaged in coastal tourism, and 2) conducting interviews with key stakeholders, such as those involved in policymaking, regulatory, and operational work, including government entities, the private sector, and non-governmental organisations (NGOs). The first activity employs purposive sampling, detailed further later, and the second activity targets representatives from each category to address relevant interview guidelines.

3.3.2 Sampling Design

In regard to the technical aspects of data collection, the study area is categorised into a customised classification to overcome logistical challenges. From the 62 officially recognised beaches mentioned in the Gunungkidul Tourism Office's publication, a purposive sampling technique is applied to select representative sites for interviews. The purposive sampling used in the research considers the following factors, consisting of physical and non-physical dimensions.

1. Tourism Strategic Zone

Tourism Strategic Zone of Gunungkidul is stipulated in Article 20 of the Regional Law of Gunungkidul Regency Number 8 of 2020 on Amendment of Regional Law of Gunungkidul Regency Number 3 of 2014 on Masterplan of Gunungkidul Regency Regional Tourism Development of 2014 – 2025. This regulation divides the regency into different zones for tourism planning and development purposes based on its tourism potential, including those in the coastal part. In terms of sampling design, this tourism strategic zone is supposed to select which beaches from the list will be the interview sites for local interviewees.

The regional law spells out 12 tourism strategic zones, each possesses distinct natural features of the regency and represents the potential of specific types of tourism. Zones 1, 2, 3, and 5 are situated in the southern part of the regency and are designated for coastal tourism development. In total, there are 39 beaches spread across those four zones, which are amongst the local government's priorities for tourist destinations. Meanwhile, Gunungkidul Tourism Office's publication states that the regency has 62 out of 110 beaches that have become major coastal attractions. For this study, both datasets were cross-checked with each other as the first stage of selection to decide the number of beach candidates that would be sampled for the interview. The cross-referencing revealed a discrepancy amongst available data sources, with certain coastal destinations cited in the regulation missing from the official list issued by the tourism office. Considering the superior legal authority, the sampling reference of this study opts to utilise the entire beach list stipulated in the regional law, as shown in Table 3.3.2.1.

Table 3.3.2.1 Strategic Tourism Zone and Coastal Tourist Destinations

Zone	Attraction Name
1	Gesing Beach, Ngedan Beach, Ngobaran Beach, Ngrenehan Beach, Nguyahan Beach, and Torohudan Beach.
2	Bekah Beach, Grigak Beach, Ngunggah Beach, Parangedog Beach, and Watu Gupit Beach.
3	Baron Beach, Drini Beach, Krakal Beach, Kukup Beach, Ngandong Beach, Ngrawe Beach, Potunggal Beach, Pulang Sawal Beach, Sadranan Beach, Sanglen Beach, Sarangan Beach, Sepanjang Beach, Seruni Beach, Slili Beach, Somandeng Beach, Sundak Beach, Watu Kodok Beach, and Watu Lawang Beach.
5	Jogan Beach, Jungwok Beach, Nampu Beach, Nglambor Beach, Pulau Kalong Beach, Sadeng Beach, Siung Beach, Timang Beach, Watu Lumbung Beach, and Wediombo Beach.

Source: Regional Law of Gunungkidul Regency Number 8 of 2020 on Amendment of Regional Law of Gunungkidul Regency Number 3 of 2014 on Masterplan of Gunungkidul Regency Regional Tourism Development of 2014 – 2025 (2020)

2. Coastal Typology

Coastal typology used in this study refers to the Shepard classification. According to Shepard (1937), coasts are classified into two categories: primary coasts (coasts formed by the dominant terrestrial geomorphic processes) and secondary coasts (coasts that are prominently formed by the marine influences). Incorporating coast typology into the sampling design is necessary because different types of coasts will affect attractiveness, tourist density, and water demand in the coastal area. Table 3.3.2.2 shows the coastal typology of each beach in different tourism zones, which is identified through visual interpretation of Google Earth's satellite imagery and supporting literature.

Table 3.3.2.2 Coastal Typology of Coastal Attraction in Gunungkidul

Zone	Attraction Name	Coastal Typology
1	Gesing Beach	Land Erosion Coast
1	Ngedan Beach	Land Erosion Coast
1	Ngobaran Beach	Structurally-shaped Coast
1	Ngrenehan Beach	Coast Built by Organism
1	Nguyahan Beach	Coast Built by Organism
1	Torohudan Beach	Wave Erosion Coast
2	Bekah Beach	Structurally-shaped Coast

2	Grigak Beach	Structurally-shaped Coast
2	Ngunggah Beach	Structurally-shaped Coast
2	Parangendog Beach	Structurally-shaped Coast
2	Watu Gupit Beach	Structurally-shaped Coast
3	Baron Beach	Marine Deposition Coast
3	Drini Beach	Wave Erosion Coast
3	Krakal Beach	Coast Built by Organism
3	Kukup Beach	Marine Deposition Coast
3	Ngandong Beach	Coast Built by Organism
3	Ngrawe Beach	Wave Erosion Coast
3	Potunggal Beach	Land Erosion Coast
3	Pulang Sawal Beach	Land Erosion Coast
3	Sadranan Beach	Land Erosion Coast
3	Sanglen Beach	Marine Deposition Coast
3	Sarangan Beach	Wave Erosion Coast
3	Sepanjang Beach	Marine Deposition Coast
3	Seruni Beach	Land Erosion Coast
3	Slili Beach	Wave Erosion Coast
3	Somandeng Beach	Marine Deposition Coast
3	Sundak Beach	Coast Built by Organism
3	Watu Kodok Beach	Marine Deposition Coast
3	Watu Lawang Beach	Wave Erosion Coast
5	Jogan Beach	Wave Erosion Coast
5	Jungwok Beach	Wave Erosion Coast
5	Nampu Beach	Marine Deposition Coast
5	Nglambor Beach	Land Erosion Coast
5	Pulau Kalong Beach	Wave Erosion Coast
5	Sadeng Beach	Structurally-shaped Coast
5	Siung Beach	Volcanic Coast
5	Timang Beach	Wave Erosion Coast
5	Watu Lumbung Beach	Volcanic Coast
5	Wediombo Beach	Volcanic Coast

Source: Dinas Lingkungan Hidup Kabupaten Gunungkidul (2021); Marfai et al. (2013); Purnomo et al. (2016)

3. Tourism Area Evolution

Tourism areas rarely remain in a status quo with their natural and cultural attractions. Tourists play a pivotal role in driving the growth of the travel industry. Their interactions with locals influence the development of tourist destinations (Gračan & Lučić, 2022). Historically, many former tourist destinations underwent gradual changes in terms of visitor numbers and development phases. However,

the internal and external uncertainties within a region can lead to fluctuations in tourist arrivals (Liu et al., 2016). Over time, tourist attractions respond by adapting to both physical and social transformations. Butler (1980) proposed the tourism area life cycle (TALC), which illustrates a structured progression of tourist sites concerning visitor numbers and related characteristics in the destination. This model divides the evolution of tourist destinations into six distinct stages, beginning with the exploration stage and eventually reaching a stagnation phase before potentially rejuvenating or declining (Guo et al., 2019).

Incorporating this theory into the sampling design ensures that interviews include beaches representing various stages of the TALC within Gunungkidul's tourism strategic zone. Initially, the study conducted a brief qualitative assessment to determine each beach's TALC stage by secondary references and satellite imagery interpretations. Table 3.3.2.3 is derived from Berry (2000), who applied TALC in a case study of the Cairns region in Queensland, serving as both an application of Butler's theory and a planning and forecasting tool. This table will facilitate the qualitative assessment, which compares 4A tourism components (attraction, accessibility, amenity, and ancillary) to determine each beach's TALC stage subjectively. Relevant data about each tourist destination has been collected and classified according to these tourism components (Table 3.3.2.4). The presence and extent of features representing each component are used to form the basis of comparison with the stage characteristics outlined by Butler (1980) and applied by Berry (2000). Table 3.3.2.5 presents the TALC stage of each beach, based on this comparison between stage features and the 4A components.

Table 3.3.2.3 Assessment of TALC Stage in Cairns, Queensland, Australia

Stage	Characteristics
Exploration	Natural and cultural attractions draw a small number of visitors, allowing a strong bond between tourists and local people.
Involvement	Indicated by growing tourist arrivals, stimulating local service establishments for tourism. Marketing strategies are initiated to attract more visitors, and the market and tourist seasons begin to flourish through tour agencies. The government is required to provide tourism accessibility infrastructure.

Development	Expansive marketing takes place due to the tourist explosion. The tourist destination starts to introduce human-made attractions, blended with the natural and cultural sights. This is followed by weaker support from the local communities, and their existing facilities will be given away and transformed into massive-scale facilities through private investment and non-domestic workers' involvement. Furthermore, the local communities hardly accept any development plans.
Consolidation	Tourism becomes the main economic sector in the region, despite the tourist arrivals starting to decline. The tourist destinations no longer build new facilities, and older ones are left behind. Otherwise, the main focus is to extend tourist seasons through more marketing strategies. In contrast, local communities feel disagreement and dissatisfaction due to disproportionate infrastructure aid.
Stagnation	Environmental, social, and economic issues arise amidst the tourism growth. Well-known resorts are less popular, and they depend on repeated visitation. The rate of property ownership turnover is high. Meanwhile, more development is set in more outback areas. The attraction ideas are imported from different regions, conflicting with the locals' nature and customs.
Decline	Higher property turnover, leading to most tourist facilities being utilised for other purposes, such as a hotel turned into an apartment. The market fails to compete with newer tourist destinations, although daily arrivals may be considerable in some areas close to the population hub.
Rejuvenation	Hypothetically reachable through a comprehensive transformation of the tourist attractions. The practical options are either introducing contemporary artificial attractions or utilising untapped natural resources more responsibly.

Source: Berry (2000)

Table 3.3.2.4 4A Components of Coastal Attractions in Gunungkidul

Zone	Attraction Name	4A Components
1	Gesing Beach	A sandy beach, equipped with a fishing harbour. Good access to reach the beach, and there are bathrooms, toilets, food stalls, and prayer rooms. The tourism awareness group manages the facilities.
1	Ngedan Beach	A sandy beach with challenging roads. The beach facilities include bathrooms, toilets, food stalls, and prayer rooms. There is a tourism awareness group that manages the tourism area.
1	Ngobaran Beach	A fairly accessible cliff beach with a Hindu temple. Bathrooms, toilets, food stalls, and prayer rooms are available, managed by the tourism awareness group.
1	Ngrenehan Beach	A sandy beach, which can only be accessed by adjoining beaches. Equipped with facilities, including homestays, which are under the tourism awareness group's supervision.
1	Nguyahan Beach	Quite accessible sandy beach, with a lot of facilities such as bathrooms, toilets, food stalls, and prayer rooms owned and managed by the tourism awareness group.
1	Torohudan Beach	Unpaved road despite having good accessibility. The beach has decent basic water-related facilities carried out by a tourism awareness group.
2	Bekah Beach	The road is steep, rocky, and hardly accessible. Only toilet facilities exist on the beach. No information about an established tourism awareness group.
2	Grigak Beach	Lack of facilities, and the road is poorly accessible. No sign of the tourism awareness group's presence.
2	Ngunggah Beach	The road is quite damaged. There are bathrooms, toilets, and food stalls under the tourism awareness group management.
2	Parangendog Beach	The beach is more easily accessed from the neighbouring beach. No facilities are to be found on this beach.
2	Watu Gupit Beach	Access to the beach is challenging, and no facilities are identified.
3	Baron Beach	Sandy beach with a good network, a wide range of facilities and local accommodations, and a well-established tourism awareness group.
3	Drini Beach	Offering a small island view, very well-accessible and equipped with various facilities provided by the tourism awareness group.

3	Krakal Beach	This beach can be accessed by any vehicle, provided with water-related facilities and local accommodations operated by the tourism awareness group.
3	Kukup Beach	Established with many facilities and accommodations in a very accessible location. The tourism awareness group manages the facilities.
3	Ngandong Beach	Located along an accessible road, the beach has multiple facilities as well as accommodation options, managed by those involved in the tourism awareness group.
3	Ngrawe Beach	The beach has quite good access, and a resort sharing the same area with the local facilities managed by the tourism awareness group.
3	Potunggal Beach	The road to the beach is rocky and half-paved. Homestay is absent, but basic facilities are present. The tourism awareness group is involved in operating it.
3	Pulang Sawal Beach	The beach is located by a highly accessible road and has many bathrooms, toilets, food stalls, and homestays nearby, managed by the tourism awareness group.
3	Sadranan Beach	The beach is close to the main road, with different types of facilities, including homestays run by the tourism awareness group.
3	Sanglen Beach	The main access to this beach is rocky and steep. Safer access is from the neighbouring beach. There are many basic facilities in the beach area. No information about the tourism awareness group.
3	Sarangan Beach	The beach is quite accessible, with some available facilities organised by the tourism awareness group.
3	Sepanjang Beach	Easy access to get to the beach. There are several bathrooms, toilets, food stalls, prayer rooms, and homestays managed by the tourism awareness group.
3	Seruni Beach	The access is extreme, covered by soil and rock. The beach has fewer facilities, under the management of the tourism awareness group.
3	Slili Beach	The beach has quite good access, equipped with several facilities, including accommodation for tourists. The tourism awareness group takes care of the tourism area.
3	Somandeng Beach	Close to a high-traffic tourist destination (Pulang Sawal Beach), very accessible and has some basic facilities owned and managed by the tourism awareness group.

3	Sundak Beach	The beach is easily accessible and there are several facilities, including prayer rooms and homestays. The tourism awareness group is in charge of daily business.
3	Watu Kodok Beach	It is well equipped with good access, several facilities even accommodations near the beach, handled by the tourism awareness group.
3	Watu Lawang Beach	Good accessibility and facilities, even a resort. The locals are involved in the tourism awareness group.
5	Jogan Beach	Offering a scenic view of a waterfall on the rocky beach. Accessible but poorly maintained road, with only toilets as the existing facilities provided by the tourism awareness group.
5	Jungwok Beach	Well accessible and has a variety of facilities managed by the tourism awareness group. A resort is established near the beach area.
5	Nampu Beach	Less accessible and fewer facilities. There is a tourism awareness group that manages the tourism activities.
5	Nglambor Beach	The road is accessible, and the beach offers many facilities, including accommodations from the tourism awareness group.
5	Pulau Kalong Beach	Cliff beach with a small island, which is quite accessible despite the lack of facilities. However, no information about the tourism awareness group.
5	Sadeng Beach	A fishing harbour, more anthropogenic influence. Good accessibility and well-equipped with facilities, but no tourism awareness group information was retrieved.
5	Siung Beach	The road is mostly damaged and poorly maintained. Nonetheless, the tourism awareness group provides supporting facilities, including homestays.
5	Timang Beach	Cliff and coral island beach, whose access is extreme. There are only toilets and food stalls provided by the tourism awareness group.
5	Watu Lumbung Beach	Rocky beach with fairly good access and equipped with several facilities by the tourism awareness group, but no tourist accommodations are available.
5	Wediombo Beach	Well accessible beach and various facilities, including tourist accommodations, are available, supported by the tourism awareness group.

Table 3.3.2.5 Tourism Area's Stage of Coastal Attractions in Gunungkidul

Zone	Attraction Name	Stage	Zone	Attraction Name	Stage
1	Gesing Beach	Involvement	3	Sanglen Beach	Involvement
1	Ngedan Beach	Involvement	3	Sarangan Beach	Involvement
1	Ngobaran Beach	Involvement	3	Sepanjang Beach	Involvement
1	Ngrenehan Beach	Involvement	3	Seruni Beach	Exploration
1	Nguyahan Beach	Involvement	3	Slili Beach	Involvement
1	Torohudan Beach	Involvement	3	Somandeng Beach	Involvement
2	Bekah Beach	Involvement	3	Sundak Beach	Development
2	Grigak Beach	Involvement	3	Watu Kodok Beach	Development
2	Ngunggah Beach	Involvement	3	Watu Lawang Beach	Development
2	Parangendog Beach	Involvement	5	Jogan Beach	Involvement
2	Watu Gupit Beach	Exploration	5	Jungwok Beach	Development
3	Baron Beach	Stagnation	5	Nampu Beach	Involvement
3	Drini Beach	Development	5	Nglambor Beach	Development
3	Krakal Beach	Development	5	Pulau Kalong Beach	Involvement
3	Kukup Beach	Development	5	Sadeng Beach	Involvement
3	Ngandong Beach	Development	5	Siung Beach	Development
3	Ngrawe Beach	Development	5	Timang Beach	Involvement
3	Potunggal Beach	Involvement	5	Watu Lumbung Beach	Involvement
3	Pulang Sawal Beach	Development	5	Wediombo Beach	Development
3	Sadranan Beach	Development			

The result from the identification of the strategic tourism zone, TALC stage, and coastal typology of the 39 official beaches in Gunungkidul is crucial for the research sampling. The researcher selected the interviewees' samples from the local category

based on those three aspects to explore water services in various coastal tourist destinations. After careful consideration, ensuring representation of all tourism zones, coast typologies, TALC stages, as well as considering accessibility and safety aspects to facilitate logistics constraints and minimise fieldwork risks, 30 selected beaches were chosen for the local interviews, as shown in Table 3.3.2.6.

Table 3.3.2.6 Sampling Location

Zone	Attraction Name	Coastal Typology	TALC Stage
1	Gesing Beach	Land Erosion Coast	Involvement
1	Ngedan Beach	Land Erosion Coast	Involvement
1	Ngobaran Beach	Structurally-shaped Coast	Involvement
1	Ngrenehan Beach	Coast Built by Organism	Involvement
1	Nguyahan Beach	Coast Built by Organism	Involvement
1	Torohudan Beach	Wave Erosion Coast	Involvement
2	Ngunggah Beach	Structurally-shaped Coast	Involvement
3	Baron Beach	Marine Deposition Coast	Stagnation
3	Drini Beach	Wave Erosion Coast	Development
3	Krakal Beach	Coast Built by Organism	Development
3	Kukup Beach	Marine Deposition Coast	Development
3	Ngandong Beach	Coast Built by Organism	Development
3	Ngrawe Beach	Wave Erosion Coast	Development
3	Potunggal Beach	Land Erosion Coast	Involvement
3	Pulang Sawal Beach	Land Erosion Coast	Development
3	Sadranan Beach	Land Erosion Coast	Development
3	Sanglen Beach	Marine Deposition Coast	Involvement
3	Sarangan Beach	Wave Erosion Coast	Involvement
3	Sepanjang Beach	Marine Deposition Coast	Involvement
3	Slili Beach	Wave Erosion Coast	Involvement
3	Somandeng Beach	Marine Deposition Coast	Involvement
3	Sundak Beach	Coast Built by Organism	Development
3	Watu Kodok Beach	Marine Deposition Coast	Development
3	Watu Lawang Beach	Wave Erosion Coast	Development
5	Jungwok Beach	Wave Erosion Coast	Development
5	Nampu Beach	Marine Deposition Coast	Involvement
5	Nglambor Beach	Land Erosion Coast	Development
5	Siung Beach	Volcanic Coast	Development
5	Watu Lumbung Beach	Volcanic Coast	Involvement
5	Wediombo Beach	Volcanic Coast	Development

3.3.3 Interview Guideline

The interview guideline (Appendix V) is formulated in corresponding with the respective stakeholders. Each accommodates questions about the roles of stakeholders

who are responsible for water services in coastal tourism. The interview guideline in this research adopted components and management measures of drinking water security in coastal communities and regions, introduced by Chen et al. (2021), which includes water sources, water treatment, water supply, and an integrated water supply system. These components were adjusted to cover at least several key parameters, including water supply, water use in coastal tourism, water management, and WASH aspects.

3.3.4 Respondents

The respondents of this study include multi-stakeholders. The interviews are conducted with particular stakeholders to collect the necessary information. The research engages with various stakeholders as follows:

1. *Kelompok Sadar Wisata (Pokdarwis)*

   Pokdarwis (tourism awareness group) constitutes an informal association of the local community involved in the daily operation of any activities within the tourism sector. This group directly experiences everyday coastal tourism activities and faces multiple associated challenges, particularly in water services. Ideally, each beach has its tourism awareness group, whose information is necessary for unveiling both the variance and disputes within the existing water service landscapes in the coastal tourism of Gunungkidul karst.

2. Relevant private sector in the tourist sites

   There are several private players in the coastal tourism industry, but this study will focus on resort activities. Through a visual interpretation of satellite imagery, a few of the resorts are recognised on some beaches along the Gunungkidul's coast. Although the number is insignificant at the moment, interviewing the resort owner can offer insights into the capabilities of private actors in utilising water and overcoming the obstacles, as well as whether their presence has affected or been affected by the water competition with the locals.

3. *Balai Besar Wilayah Sungai (BBWS) Serayu-Opak* (Serayu-Opak River Basin Organisation)

   RBO is a critical participant as it holds information about water resources planning in a specific catchment region. In this case, Gunungkidul's coast is on the downstream of the Serayu-Opak Catchment. It is essential to gather

information regarding the water provision for coastal areas as part of the river basin. Furthermore, RBO also participates in policy implementation. Thus, obtaining information from them is crucial for understanding the policy mechanisms and how they accommodate or solve any issues related to water provision for tourism purposes in coastal areas.

4. *Perusahaan Daerah Air Minum (PDAM) Tirta Handayani Kabupaten Gunungkidul* (Tirta Handayani Regional Drinking Water Utility of Gunungkidul Regency)

PDAM is the main provider of clean and safe water in the region. This water utility serves different categories of consumers, including those in the economic sector, such as tourism. Therefore, interviewing the company will provide detailed information about the scope of their current work in supplying and managing the water resources, their water service quality within the coastal tourism context, and the forthcoming plans to address any issues related to the water service.

5. Tourism Office of Gunungkidul Regency

The tourism office is responsible for planning and monitoring the implementation of tourism activities in the region. As previously stated in the introductory section, the region's vision to strengthen its economy through tourism has encouraged the government's plan to expand coastal tourist attractions to anticipate future tourist arrivals. It has begun to raise concerns about coastal tourism, particularly the water management in the tourist areas and their surroundings. Meanwhile, the region struggles with the existing water supply challenges due to its vulnerability to water scarcity. The information from the tourism office will be useful to tap into areas the government needs to improve to ensure the responsible and sustainable use of water for tourism that does not damage the environment and harm the local community.

6. Environment Office of Gunungkidul Regency

The environment office has a wide range of expertise and works on environmental issues, including water resources. The environment office also employs a catchment-based approach to bring solutions. In this study, their information is necessary to understand their roles in both policymaking and

policy enforcement as part of the government, as well as obtaining insights into their coordination with other government bodies, such as the tourism office and RBO.

7. *Wahana Lingkungan Hidup Indonesia (WALHI)*

WALHI is one of the Non-Governmental Organisations (NGOs) advocating for environmental issues across many regions in Indonesia, including the Gunungkidul area. The presence of NGOs is vital in policy implementation as they work on raising awareness, assisting the government in untouched areas, and catalysing change within the community. The interview with WALHI as a representative of NGOs is expected to shed light on their ongoing work and the areas they can influence in the context of coastal tourism, especially water management.

8. Academia working in water science and/or tourism fields

Academia plays a crucial role in providing relevant theoretical frameworks and scientific evidence on the issues discussed, thereby enabling informed decision-making. The engagement of their expertise is powerful in building a more accountable policymaking process. In this case, the interview aims to identify their involvement and contributions, especially in water issues within coastal tourism.

Respondents are recruited according to the research data requirements. For the local category, people are recruited in the field via a direct and impromptu approach without scheduling any appointments. The researcher arranged interview appointments for the non-local category through either an in-person appointment or via email.

3.4 Data Processing and Analysis

3.4.1 Data Processing Methods

The collected data went through recapitulation and were processed using NVivo. By using NVivo, the interview data were classified to interpret various findings as per the research questions. It can determine the current situation of coastal tourism according to the interview guideline parameters. Certain findings are visualised spatially by employing ArcGIS Pro, where data acquired from field observation during the interview are embedded in a topological map for this research.

3.4.2 Data Analysis Methods

The research uses two analyses to answer the research questions. The processed data are elucidated using the thematic analysis to identify, analyse, and report pattern within a dataset (Braun & Clarke, 2013); and a spatial analysis to improve the contextual depth and spatial rigour of the qualitative study across the social sciences, and the practicality for researchers and readers (Marx, 2023; Rucks-Ahidiana & Bierbaum, 2015). The thematic analysis emphasises the ongoing water service in the coastal tourism of Gunungkidul, reflecting interview data with all stakeholders. The social-ecological system is the fundamental approach in this study to explain the importance of water services in coastal tourism activities and to delve into the interrelationships between water and tourism aspects in Gunungkidul. The social-ecological approach refers to the following scheme from Heslinga et al. (2017), which highlights the interrelations and interdependencies of both the landscape and tourism system, and also the dynamic concept in which both systems constantly change due to the external influences and reciprocity of feedback loops, whilst the spatial analysis assists in visualising the discrepancy, variation, and challenges of the water service across the selected beaches in the coastal karst tourism system.

3.5 Ethical Considerations

This study was conducted with strict adherence to ethical principles to safeguard the rights, dignity, and well-being of all participants throughout the research process. Before beginning the study, the researcher completed two training courses: Research Integrity: Introductory Core Course and Research Involving Human Participants, as prerequisites for obtaining ethical clearance from the University of Oxford Central University Research Ethics Committee (CUREC). Applying to CUREC was a mandatory step to ensure that neither the researcher nor the participants would face any risks or disadvantages during the study. The CUREC application was approved, with the reference number SOGE C1A 24 74, authorising the researcher to collect data from human participants.

The research also required a travel risk assessment due to overseas fieldwork for data collection. The researcher implemented appropriate measures, as the fieldwork was deemed a medium risk, which was approved by the Head of the School of Geography and the Environment under approval number: AC-2024-NC-085. Additionally, the researcher sought ethical clearance from the relevant local institution, which was granted with reference:

642/KE.01/SK/07/2024. These approvals provided legal permission to carry out data collection during the fieldwork.

The researcher supplied an information sheet and an oral consent form to each participant, ensuring they were fully informed about the research's purpose, procedures, and their right to withdraw at any time without providing reasons or facing negative consequences. Participants could choose to be directly quoted, indirectly quoted, or not quoted at all. To protect confidentiality, the researcher employed pseudonymisation, and no personally identifiable data is disclosed in this dissertation. The researcher securely stored separate documents containing the real names and pseudonyms of participants.

Data collection, analysis, and reporting were carried out with care and integrity. The collected data, including the oral consent forms, will be securely stored on the researcher's drive for several years after the study's completion, accessible only by the researcher, their supervisor, or principal investigator. No conflicts of interest that could influence the research outcomes were diagnosed. Furthermore, the researcher appropriately utilised and referenced open-source data presented in this dissertation.

SECTION IV
RESULTS AND DISCUSSION

This section reexamines the three research purposes, which will be divided into three subsections correspondingly. Each subsection includes the analytical results from interviews conducted with various stakeholders. Additionally, each section provides the underlying rationale of the phenomenon under investigation, supported by the relevant scholarly perspectives.

4.1 Existing Water Service Landscape in Coastal Tourism of Gunungkidul Karst (Research Question 1: How is the variation of water service systems for tourism activities across the coastal zone of Gunungkidul?)

The first research question explores the existing water provision in coastal karst tourism from various perspectives. The interview with several stakeholders has unveiled several topics across the physical and non-physical aspects of the coastal karst tourism in the region, including the characteristics and influences of the karst ecosystem, the tourism's day-to-day business and its development level, the current face of the region's water governance and policy, the water service operations across coastal tourist destinations, and the wastewater management within the tourism attractions. These topics are elaborated in the following thematic paragraphs.

4.1.1 Theme 1: Overview of Coastal Karst Landscape Features

Gunungkidul is geologically located in more than one natural landscape, one of which is the karst terrain that dominates the southern part of the region. This particular area is unique in terms of the complex interactions between karstic morphologies and coastal and marine influences, dynamically creating challenging water resource properties for the local water utilisation for both household and non-household use.

In general, a karstic region is hydrologically abundant throughout the year, even in the dry season, because of the overall high porosity and dependable discharge (Interviewee A1: Representative from academia), as similarly described by Sahrina et al. (2020) as gigantic freshwater tanks whilst having the sensitivity and vulnerability of karst environment to contaminant as a distinct nature caused by its hydrologic and hydraulic properties (Butscher & Huggenberger, 2009; Campanale et al., 2022; Kaçaroğlu, 1999; Peng et al., 2025; Schorr et al., 2024). However, as the study area lies in an intricate geological setting within a transitional zone (coastal zone), the coastal

karst of Gunungkidul is constrained by the limited water availability and persistent complexity associated with its exploration and utilisation, despite being located in the downstream of a river basin (Interviewee A1). In the following interview, Interviewee A1 explained that the water availability in coastal karst depends on the presence of marine deposits, which affects the spatial distribution of the water source.

> *"Lithologically, the coastal Gunungkidul consists of thick limestone formations with overlaying marine deposits derived from limestone, which means the water availability depends on the properties of these deposits. Theoretically, this region demonstrates finite water availability, but occasionally, underground river networks appear along the coastline, allowing water to be utilised. Additionally, further north, where alluvium layers are slightly thicker, natural springs may emerge, although this is quite a rare phenomenon. For instance, there is a small spring at Sundak Beach and a larger one at Baron Beach and Ngrenehan Beach. Essentially, water availability remains limited in the region."* (Interviewee A1).

The uneven distribution of water resources across Gunungkidul is reflected in its responsive topography. The region is unfavourably potential for the surface water resources (Interviewee G5: Representative from the corresponding RBO). As surface water bodies are less prominent in its landscape, Gunungkidul has been associated with the stereotype of a water-scarce region, as articulated by the subsequent statement.

> *"Given the familiarity of the dry landscape character in Gunungkidul, I have not heard people commonly relying on surface water resources."* (Interviewee G5).

Interviewee G4 (Representative from the environment office) also observes that, in this case, some parts of the region have surface water resources but are typically sensitive to hydro-climatological factors, which have shrunk in the past decade, becoming less dependable and resilient. This vulnerability has led to a greater reliance on groundwater.

> *"We conduct an annual report on the Regional Environmental Performance Information Document (DIKPLHD). We provide a list of the available water sources in the region, including 250 telaga (small lakes). Unfortunately, we have*

not done any updates since 2010 when we produced our Regional and Spatial Plan Policy (RTRW). I doubtfully think the figure remains the same as many have dried up, even with the absence of water." (Interviewee G4).

The dependence on groundwater demonstrates the significance of groundwater as the most promising water resource in the region. Some coastal parts exhibit higher availability and accessibility to groundwater due to underground water movement and accumulation towards these areas. Regarding this, Interviewee G4 also emphasised:

"Our office works on the Environmental Protection and Management Plan (RPPLH), consisting of aquifer identification and geohydrology zonation, from which we understand the southward movement of groundwater flow and accumulation. No wonder coastal Gunungkidul has more productive groundwater." (Interviewee G4).

The common manifestation of groundwater resources in this region is underground rivers, whilst some of them appear via seepages, cavemouths, fissures, or faults and accumulate on the surface (Interviewee G4). Groundwater, in the form of underground rivers, is considered the most promising water source to supply locals' needs, albeit seasonal variability exists.

"I think Seropan has a highly potential perennial underground river that flows continuously regardless of seasonal changes. The one in Ngobaran has lower flow during the dry season. Similarly, the underground river in Bekah is shrinking every dry season and potentially mixing with seawater." (Interviewee G4).

Notwithstanding, the geographical variation in its occurrence consequently shapes the water utilisation and access. Interviewee N1 (Representative from an NGO) stated:

"Gunungkidul karst exhibits a spatial variance that results in different levels of water accessibility. For instance, in the Wonosari Basin, people need to reach a deeper water table to abstract or pump water, which is a costly investment. A shallower water table is usually found near the coastal area, making water more accessible." (Interviewee N1).

The complexity of landscape factors contributes to the hydrological attributes in Gunungkidul. Water sources are unevenly distributed, especially in the karst area, where access to groundwater varies from one place to another. The coastal karst zone is a convergence zone between emerging tourism industries and domestic activities, exhibiting overlapping heterogeneous demands and behaviours in water consumption, as well as a spatial interface of the intersection of multiple stakeholders' interests. In light of understanding the relationship between water resources and tourism development, the subsequent themes will explore the current state of coastal tourism in Gunungkidul karst and how existing water services support the tourism industry.

4.1.2 Theme 2: Coastal Karst Tourism Development

The coastal karst zone in Gunungkidul is the hotspot for coastal tourism. According to the interview with the representative of the tourism office (Interviewee G2), this area has been developed as designated coastal tourism since the early 2000s, within which 80 beaches have been established as official tourist attractions. The government has set an ambitious target to expand the tourism industry as per the following statement:

> *"The government requests to open four new tourist attractions every year. We welcome proposals coming from either the government itself or the private sector. This target is legally stipulated in our work plan (RENJA) and strategic plan (RENSTRA) document."* (Interviewee G2).

This trend has grown a concern amongst environmental advocates, including an NGO in the region.

> *"First and foremost, we work on water issues along with tourism development. We consider tourism development as a critical concern due to its strong relation with water availability."* (Interviewee N1).

This statement provides a justification considering the limited water resource factors in Gunungkidul. Looking into the government's plan, the extensive coastal tourism development plan will increase water stress. Consequently, it potentially heightens underlying tensions across different users, depending on the growth level of each tourist destination. In this theme, therefore, the study will elaborate on the state of tourist destinations in the strategic tourism zone of Gunungkidul.

1. Zone 1

Land erosion coasts and coasts built by organisms (Figure 4.1.2.1) are the most common coast typology in this zone. Purnomo et al. (2016) found that these types of coasts are ideally developed as coastal tourist attractions. Despite a high potential in tourism, most beaches in Zone 1 are still at the involvement stage, where the tourism area has indicated growing visitors in a small-scale establishment. Ngedan Beach was temporarily closed during the data collection phase, and data analysis about this beach was not possible. In this stage, the water usage is not intense due to the absence of hotels or resorts. The most frequent water-consuming activities are bathrooms, toilets, and restaurants.

(a)

(b)

(c)

Figure 4.1.2.1 Coast Built by Organism: (a) Ngrenehan Beach, (b) Nguyahan Beach, Land Erosion Coast: (c) Gesing Beach

Source: Courtesy of the Author (2024)

2. Zone 2

Zone 2 dominantly constitutes structurally-shaped coasts, indicated by challenging access and massive cliff structure. Due to safety risks and extreme inaccessibility, data collection could not be fully carried out. There were only tourists in

Ngunggah Beach (Figure 4.1.2.2), but no sign of locals working on the beach for conducting the interview. Arguably, with the limited access, the tourist arrivals may not be as high as in other zones. Consequently, the tourism area grows slowly and demands less water supply for its activities.

Figure 4.1.2.2 Structurally-shaped Coast: Ngunggah Beach

Source: Courtesy of the Author (2024)

3. Zone 3

In contrast to Zone 1, Zone 3 exhibits domination of active marine influence on their coasts. Secondary coasts (Figure 4.1.2.3) in the zone account for 14 out of 17 beaches sampled for this research. Because of the strong marine processes, this zone has diverse landforms such as pocket beaches, barrier beaches, barrier spits, and extensive stretches of sandy beaches with straight or irregular coastline patterns, some distinct features that are naturally appealing for tourism (Marfai et al., 2013). Therefore, there are more beaches open for coastal tourism in this zone, making it the heart of coastal tourism in Gunungkidul.

(a) (b)

Figure 4.1.2.3 Marine Deposition Coast: (a) Watu Kodok Beach,

Wave Erosion Coast: (b) Drini Beach

Source: Courtesy of the Author (2024)

Following the likelihood of more intense activities and increased popularity, this zone anticipates more tourist arrivals and growing water demand in the future. Most beaches here are at the development stage, with a few others at the involvement stage. As a consequence, the tourism areas require more adequate infrastructure to support the water supply for tourist accommodations. Only Baron Beach, which falls into the stagnation stage, exhibits slower tourism intensity, as newer destinations have emerged. Interviewee L11 (Local at Sundak Beach) also reflected a similar thought:

> *"I have seen how significant the growth of coastal tourism has been. You can discover a lot of new beaches nearby, attracting more visitors, whilst the older destinations have lost popularity."* (Interviewee L11).

There was no interview conducted in Sanglen Beach. During the data collection phase, the beach was closed by the Sultan of Yogyakarta due to the social conflict over beach utilisation as a tourism area, as affirmed by the following interview:

> *"There was an ongoing resort development that restricted the locals from accessing Sanglen Beach."* (Interviewee N1).

4. Zone 5

Zone 5 consists of both primary and secondary coasts (Figure 4.1.2.4), with the former comprising the majority. Despite being further and isolated from the other three zones, the tourism stage is more progressive. More beaches are at the development stage compared to ones in Zones 1 and 2 combined.

(a) (b)

Figure 4.1.2.4 Wave Erosion Coast: (a) Jungwok Beach,
Volcanic Coast: (b) Siung Beach
Source: Courtesy of the Author (2024)

Tourism development and water resources are two inseparable equations in the context of coastal tourism. On the one hand, tourism activities necessitate a sustained water supply to maintain their operation. On the other hand, water resources are constrained by landscape factors, and tourism itself could impact their sustainability. Accordingly, the corresponding entities' roles become pivotal in addressing issues that intersect between the water and tourism sectors, where parties on both sides should be able to identify the root causes and provide alternatives that prioritise and accommodate communal interests.

4.1.3 Theme 3: Water Governance and Policy in Coastal Karst Tourism

Ideally, the development of tourism considers the potential of water resources and associated risks, as well as the capacity of these resources to support tourism industries. However, as other sectors also require water, implementation of responsible water use is necessary, which necessitates a solid regulatory framework. This theme will discuss the profile of water governance and policy implemented directly and indirectly within the tourism sector.

In the Gunungkidul case, there are several stakeholders involved in water resource affairs. The government has the most authority in planning, managing, and monitoring the policy implementation. Non-government sectors do not appear to have exerted any influence on controlling the water resource in Gunungkidul. The river basin organisation (RBO) and PDAM are the principal stakeholders in water supply and demand management. RBO works primarily in raw water provision, from which PDAM extracts it and proceeds to water treatment before distributing the clean water to the consumers (Interviewee G5: Representative from local RBO).

> *"We will hand over the management to the local government after we finish the development of the raw water supply system. Eventually, the government will hand it over to the water utility. Simultaneously, the local government is also responsible for establishing the conservation plan with the relevant stakeholders."* (Interviewee G5).

> *"Our work is based on the service unit, where every unit serves up to four districts, has its own system, and takes water from a certain water source. Some extract water from underground rivers, others use deep water wells, rivers, or*

springs. We treat the water from the underground rivers because it is murky every rainy season." (Interviewee G1: Representative from PDAM).

Some other actors, such as the tourism office and the environment office, are associated through their indirect interventions.

> *"As I mentioned earlier, a development requires integration, collaboration, and cooperation with other stakeholders, including solving water issues through clean water provision for both tourism and the people behind it. We have a strong cooperation with PDAM. The utility pumps water out of the Bribin underground river near Baron Beach, one of our major tourist destinations, stores the water in huge reservoirs and also delivers it eastward through their pipeline networks. We have a cooperation with the utility and other stakeholders in water provision and management."* (Interviewee G2).

Meanwhile, the environment office's roles are less technical compared to the responsibilities of RBO and PDAM. The environment office assists in water source inventory and monitoring, as well as water conservation from a soft engineering approach. Moreover, they also work on environmental guidance to support the utilisation of natural resources, including water. The environment office actively engages with the NGO and community in accommodating solutions for both water and tourism issues.

> *"We do water quality surveillance on our water sources. Water sources designated for drinking water, such as water wells, are monitored by the health department, whilst we solely focus on surface water monitoring. We regularly check the water quality of rivers, reservoirs, and seawater."* (Interviewee G3: Representative from the environment office).

> *"When we talk about our office's role and responsibilities, our focus is on water conservation. The water conservation programme is deployed in the upstream catchment as per our RTRW through forest protection to maximise infiltration and minimise surface runoff. This strategy hopefully maintains the hydrological cycle within the karst system. Similarly, we also do land cover quality monitoring, involving a tree planting programme with the Watershed*

Management Agency (BPDAS) to boost water conservation around water sources in Gunungkidul." (Interviewee G4).

"We are usually involved in environmental studies with the environment office. We have collaborated with the tourism office. We have built a locally based community network, majorly attended by youth, to discuss and address tourism issues in Gunungkidul. Similarly, we have a group of communities focusing on water access." (Interviewee N1).

The environment office takes preventive measures by consistently implementing natural resources management through environmental documents as an administrative procedure that should be fulfilled by any party intending to abstract water, subject to the scale of their operations. The office is responsible for ensuring that the water utilisation does not threaten water sustainability.

"Admittedly, many tourism businesses along the Gunungkidul coast, such as hotels, resorts, and restaurants, consume water every day. To ensure responsible water consumption, one of our divisions will request legitimate environmental documentation from the corresponding tourism operators, one of which should cover water use and wastewater plan." (Interviewee G4).

"The Statement of Environmental Management and Monitoring Capability (SPPL) is part of our land use and natural resources control, along with the Efforts for Environmental Management and Monitoring (UKL-UPL). It depends on how much water they extract. The utility has various capacities. If they pump out a huge amount of water, they need all these environmental documents. Otherwise, small-scale utilities only require the statement letter." (Interviewee G3).

The environment office also assists the public works office in water use monitoring across different groups of consumers.

"The public works office handles more water affairs. I am also part of the superintendent team at the provincial level, assisting in monitoring the water consumption of big enterprises, hotels, and any companies utilising deep

groundwater. We ask them to install a water metre to enable us to monitor their water consumption so that we can evaluate it subsequently." (Interviewee G4).

Some interviews suggest that most stakeholders have performed their individual mandates competently, although coordination remains fragmented. The existing system does not emphasise any integrated and end-to-end policy to manage water-tourism affairs in the coastal environment setting, where each stakeholder works in a silo. The interaction amongst them reveals the absence of a well-structured integration, reflecting the need for a stronger and more coherent framework to guide collective action and facilitate issue-specific responses. Lack of a robust and contextually responsive framework potentially induces miscommunication between water resources and tourism development governance. In other words, it could trigger disputes in utilising water for tourism purposes.

4.1.4 Theme 4: Variation of Water Service Across Coastal Karst Tourism

In this study, the natural physiography and the existing water governance are factors that shape water service landscapes in coastal tourist destinations. These landscapes may alter due to pressures from tourism development, as it stimulates disturbance in the system. Increasing tourist arrivals require adjustments to the current establishments. With the natural threats of water scarcity, the relevant stakeholders are challenged to respond and adapt accordingly. Therefore, in this section, it is necessary to identify and explore the elements of water service and its geographical variance within the coastal karst tourism zone.

The karst landscape poses water resource challenges to meet tourism water demands. Tourism water demands in the Gunungkidul coast include water for bathrooms, toilets, food kiosks, tourist accommodations, worship places, drinking water and non-drinking water. The demand could exceed household water consumption, particularly during peak season, as per the statements below:

"It is incredibly significant, especially every weekend. Coastal community spends most of their day on the beach working in their food kiosks and providing bathrooms and toilets for tourists. They are rarely at home during the day, making less household water consumption, whilst consuming more water on the beach." (Interviewee G1).

> *"We are very consumptive, especially during the weekend and peak holiday. We usually welcome thousands of either domestic or international tourists. Other days, we normally have 200 visitors."* (Interviewee P1: Representative from resort management).

The following information, quoted from the interviews, shows several water sources that the local people use in the coastal tourism area, such as underground rivers, water wells, springs, rainwater, and bottled/gallon water through certain water service providers.

> *"From what I have heard, the water supply in some areas has been provided by either PAMSIMAS or PDAM. Near Baron Beach, there is a huge water storage or reservoir to help distribute water from the Bribin underground river system to the adjacent beaches. Gunungkidul also has abundant groundwater resources being utilised through deep water wells, with depths ranging from 50 to 60 metres. The local communities in the southern Gunungkidul have utilised water wells as a widespread practice"* (Interviewee G4).

> *"I am surprised to learn that at Baron-Krakal Beach complex, the established pipeline from PDAM has not been fully utilised recently, as they are well-sufficient with their water well in Banyutibo. During peak demand, they still have enough water to operate their businesses. Occasionally, they need to call water trucks to support their water supply, especially at well-developed beaches like Pulang Sawal Beach, which has many restaurants, bathrooms, toilets, and lodgings."* (Interviewee G2).

The interview conducted on 27 beaches revealed the difference in the number of water sources for tourism activities. To begin with, 85% of coastal tourist destinations have more than one water source for their daily operations, and the rest rely on a single source (Figure 4.1.4.1). This figure suggests that the presence of multiple water sources can serve as a mitigating factor against water scarcity. People in Malawi tend to depend on various water sources more during the rainy season due to seasonal availability (Cassivi et al., 2021), and people in semi-arid regions such as Ceará, Brazil, who have multiple supply sources like cisterns and water tankers, report a greater sense of water

security (Tomaz et al., 2023). These examples indicate that such diversity in water sourcing can be strategically beneficial for reducing vulnerability to water insecurity.

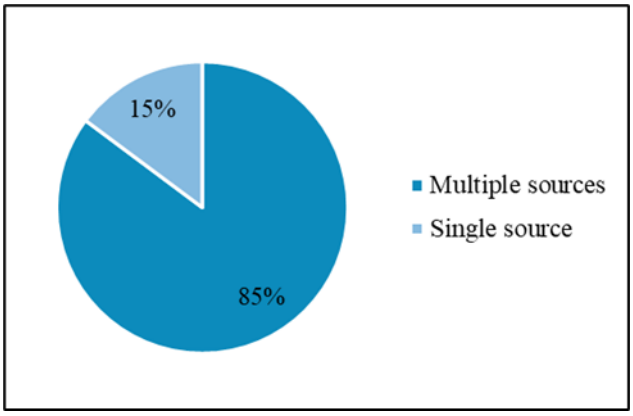


Figure 4.1.4.1 Proportions of Water Source Used in the Gunungkidul Coastal Tourism
Source: Data Analysis (2025)

Some beaches use a single source due to the lack of alternative water sources in the vicinity and a water service gap. The unavailability to access the water continues to persist because the existing public pipeline has not reached further or more isolated regions. For instance, some beaches on the eastern coast of Gunungkidul, such as Nglambor Beach and Potunggal Beach, have supplied their daily water from merely a seepage or cave mouth (Figure 4.1.4.2). Although these beaches have no supporting water sources, the spring has an abundant flow and remains available even in the dry season.

> *"You have no idea how plentiful it is. I believe this seepage has a significant amount of water because it emerges from the deepest part of the underground flow. It remains steady even during the dry season. The local community here really cares for the seepage because it is the only water source we have."* (Interviewee L6: Local at Nglambor Beach).

> *"Our water comes from a tuk (seepage). It's under the three over there, and people built a concrete perimeter wall to protect it from tidal waves. This source is always available. Despite its gentle flow, the water will concentrate and accumulate abundantly over time. If I am not mistaken, it appears from a small fissure, from a rock tunnel."* (Interviewee L7: Local at Potunggal Beach).

(a)

(b)

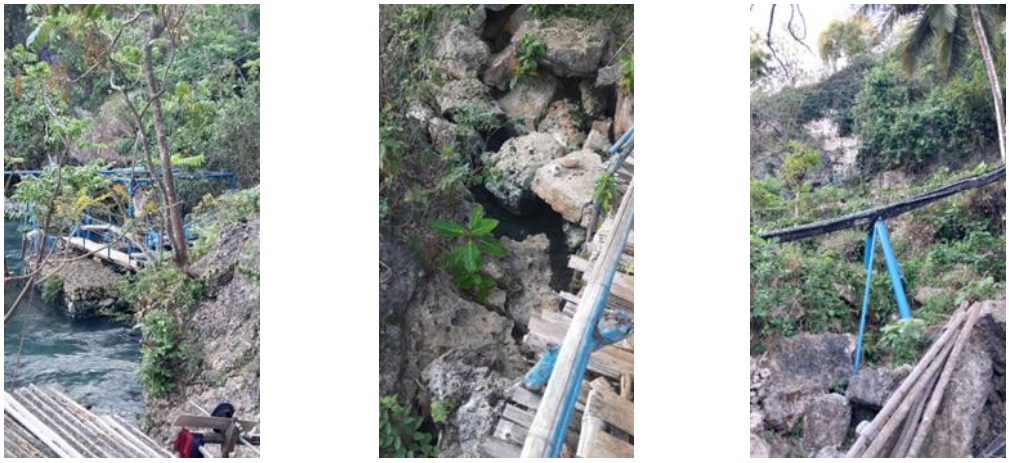
Figure 4.1.4.2 Water Sources in (a) Nglambor Beach, (b) Potunggal Beach

Source: Courtesy of the Author (2024)

Another reasonable factor is that the existing source can meet the overall water demand for multiple purposes. In short, reliance on PDAM service is higher in the western coastal Gunungkidul compared to the eastern region. This phenomenon is observable at Ngrawe Beach and Baron Beach, where the PDAM Baron Unit fully supplies its tourism water demand. Geographically, these three beaches are relatively close to the PDAM distribution network and its source (the underground rivers), where PDAM has their water intake installed (Figure 4.1.4.3). In other words, the relative distance to water sources also influences water accessibility, and it makes a significant difference knowing that the presence of water sources in a karst landscape is uneven. According to Guo et al. (2021) and Stevanović et al. (2024), spring water discharge, which is crucial for many communities, is not uniformly distributed but varies with topography and the distance to karst recharge areas, which can lie at significant depths.

> *"We use water from the PDAM Baron for bathing and drinking. We used to have water wells, but the water was brackish for drinking, and tourists did not favour it. Therefore, someone subscribed to the current service (PDAM) and built a local distribution line on this beach to deliver water to all the food kiosks to supply their drinking water."* (Interviewee L21: Local at Ngrawe Beach).

> *"We have no other sources here. PDAM fully supply our water."* (Interviewee L22: Local at Baron Beach).



(a) (b) (c)

Figure 4.1.4.3 Underground River in Baron Beach: (a) The Outlet, (b) Rock Fissure, (c) Transmission Pipeline (Transporting Raw Water to the Utility)

Source: Courtesy of the Author (2024)

Meanwhile, other beaches have gained access to different options due to the increased availability of alternative water sources. Additionally, this phenomenon appears to be closely linked to the behavioural patterns of consumers, including people working on the beach and tourists. One such pattern is their preference for using a particular water source for a single purpose, especially for drinking water, as illustrated by Figure 4.1.4.4. The pie chart indicates that coastal tourism areas that deliberately provide gallon/bottled water for drinking water account for 52% of the total. The remaining 48% source their drinking water from non-gallon/bottled water sources. This suggests that more than half of the sampled coastal tourism areas depend on different sources to fulfil their non-drinking water needs.

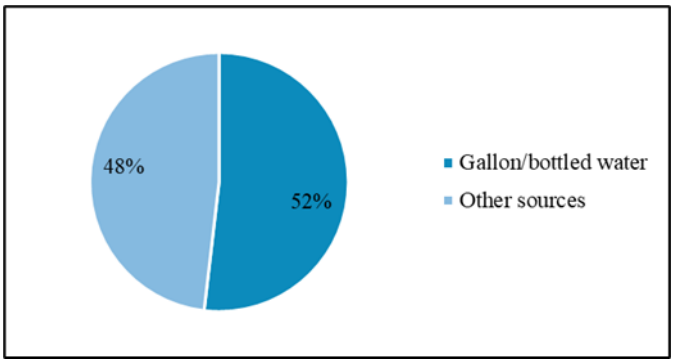


Figure 4.1.4.4 Proportions of Water Source Used for Drinking Water in the Gunungkidul Coastal Tourism

Source: Data Analysis (2025)

This tendency is apparently attributable to the variability of water quality characteristics across different water sources. Gallon/bottled water (Figure 4.1.4.5) has become a preferred source for drinking water, described as having better quality in terms of taste and clarity compared to water from PDAM, SPAMDes, and water truck services, which contains a high amount of carbonate minerals. These three services obtain water from the identical sources, groundwater or an underground river, in which the water cloudiness is prominent.

Figure 4.1.4.5 Gallon/Bottled Water Delivered by Local Transport

Source: Courtesy of the Author (2024)

In response to the cloudy water, locals resort to practising additional water treatment themselves. In some instances, people make water wells and find that the water quality is better. Through the following interviews, most people in the tourism areas which subscribe to PDAM, SPAMDes, and water truck service have similar views about the water quality.

a. Interviews with locals who subscribe to water truck service

"The water is quite clear yet cloudy. It contains considerable limestone minerals. Thus, we need to boil the water, let the limestone minerals settle, and filter it before consuming it. Every water source you find in this region has typical characteristics. We always buy gallon/bottled water from the nearest water kiosks for drinking." (Interviewee L1: Local at Jungwok Beach).

"It looks clear but a bit cloudy because it contains rich limestone minerals. I guess people here should use gallon/bottled water for drinking." (Interviewee L2: Local at Wediombo Beach).

"I think it is clear in the dry season, yet it gets murky every rainy day. It is also cloudy due to rich limestone minerals." (Interviewee L4: Local at Watu Lumbung Beach).

b. Interviews with locals who subscribe to PDAM

"We usually use the same water source for drinking. We boil the water from PDAM for our daily use." (Interviewee L9: Local at Pulang Sawal Beach).

"We use gallon/bottled water for consumption since water from PDAM and water wells contains high amounts of limestone minerals." (Interviewee L15: Local at Krakal Beach).

"They highly contain limestone compounds." (Interviewee L17: Local at Drini Beach)

"I do not buy gallon/bottled water for drinking. Instead, I take the water from PDAM, boiling and filtering it to remove the limestone minerals." (Interviewee L18: Local at Watu Kodok Beach).

"We think that the water from PDAM contains a considerable amount of limestone minerals." (Interviewee L19: Local at Sepanjang Beach).

"For drinking, we must boil the water beforehand. I prefer gallon/bottled water for drinking. I have the supplies ready at home, and I can bring them with me to the beach. Water from PDAM is rich in limestone minerals." (Interviewee L20: Local at Kukup Beach).

"The water from both water trucks and PDAM has similar quality since they extract water from the same source. It is clear in appearance, yet a bit cloudy. We must boil and filter to remove the limestone minerals every time we want to drink." (Interviewee L23: Local at Torohudan Beach).

"The water quality is quite good, but we are a bit concerned about its cloudy appearance. We have to boil it before we can use it." (Interviewee L24: Local at Ngrenehan Beach).

"The water we use for bathing and cooking comes from the same source utilised by PDAM. Because they have cloudy water, we prefer gallon/bottled water for drinking." (Interviewee L25: Local at Ngobaran Beach).

"We treat water from PDAM. We boil the water, store it in a water jug to let the limestone minerals precipitate, and then filter the water. We do it every day, so we have no problem." (Interviewee L26: Local at Nguyahan Beach).

c. Interviews with locals who subscribe to SPAMDes

"It is good like other freshwaters in terms of taste and clarity, even though it is cloudy. For drinking purposes, we will boil and filter the water to remove the limestone minerals." (Interviewee L10: Local at Somandeng Beach).

"The water from SPAMDes has better quality than any other source. Although it is not salty or brackish, we must boil and filter it because of its highly suspended limestone contents." (Interviewee L12: Local at Ngandong Beach).

"Water wells for me as it has less cloudiness than the water from SPAMDes. If I could imagine, the amount of limestone minerals in two litres of water could fill a small teapot." (Interviewee L13: Local at Sadranan Beach).

"We heavily depend on SPAMDes because this is the best option we have. This beach's location is unfavourable for building a water well. A few people have containers for rainwater harvesting, an alternative drinking water, since our current water contains limestone minerals in a considerable amount. Villagers even prefer gallon or bottled water for drinking water because of its better taste." (Interviewee L14: Local at Slili Beach).

These interviews have recognised that most water sources in the Gunungkidul coastal karst have common properties. The cloudy appearance of the water describes the presence of limestone compounds. The locals have naturally adapted to this situation by practising the traditionally inherited boiling and filtering technique for

better quality drinking water. For those using water from PDAM, this phenomenon can also indicate low performance of the existing water treatment. Given that PDAM units are being equipped with a water treatment facility each, the limestone compounds in the water are still considered high.

The interviews also revealed that some coastal tourist destinations have different water sources to supply their overall tourism water demand. Figure 4.1.4.6 illustrates water source diversities utilised in the Gunungkidul coastal karst tourism areas. The pie chart indicates that gallon/bottled water dominates the figure, accounting for approximately one-third of the sampled beaches, making it a vital water source for the tourism business in the region. More beaches provide gallon/bottled water due to tourist preference for drinking water. This figure is followed by underground rivers (PDAM) and borewells (SPAMDes) for only a five per cent gap. Lower fractions from these two sources are strongly linked to the water quality properties, particularly the limestone mineral content. The proportion of users sourcing water from seepages/cave mouths and dug wells is quite similar, with only a two per cent difference. The people in the region rarely use rainwater to support the coastal tourism activities.

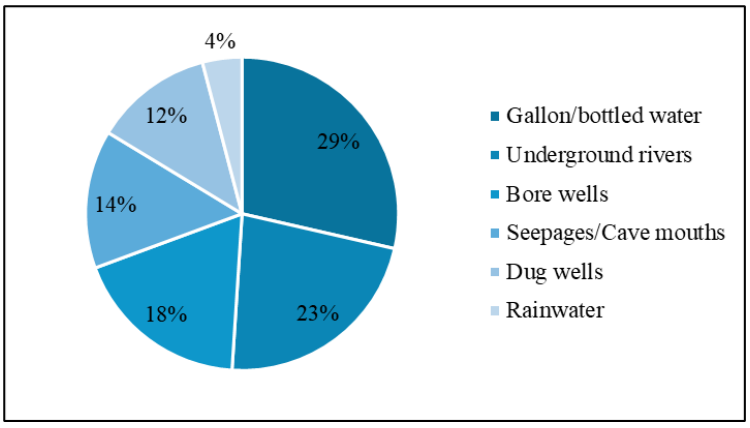


Figure 4.1.4.6 Proportions of Primary Water Sources in the Gunungkidul Coastal Tourism
Source: Data Analysis (2025)

In some beaches, dug wells are either primary or supporting water sources. People tend to create dug wells because of their performance compared to other sources. Water wells generally contain fresher, safer, and better water, as experienced by Interviewee L8 (Local at Watu Lawang Beach), contrary to the PDAM or SPAMDes services. Similarly, Interviewee L27 (Local at Gesing Beach) was surprised by the clarity and freshness of the water from the dug wells, despite their proximity to the coastline. People in Krakal Beach still use dug wells because they perform better than

the water served by PDAM, despite its seasonal variability (Interviewee L15). Likewise, people in Sarangan Beach also have water wells because of good reliability and performance reasons, although salinity changes from dry to rainy season are observed (Interviewee L16: Local at Sarangan Beach). Both the variability of flow and the salinity of water from dug wells are identified in Sepanjang Beach, as mentioned by Interviewee L19. Interviewee L19 also stated that the preference for using water wells to supply their tourism water demand is due to lower economic costs and maintenance efforts. Interviewee L13 also prefer utilising water wells for similar reasons:

> *"I can spend half of my expenses for the SPAMDes service by providing more supply from the water wells. I only need to buy diesel to fuel the pumping machine. I have not bought another pumping machine since 2012. I put more effort into generating the power so I can cut my expenses."* (Interviewee L13).

Meanwhile, people have the least preference for rainwater stemming from the availability of other better water service options, precipitation being unpredictable, lack of proper rainwater harvesting facilities (Figure 4.1.4.7), and financial constraints, which are noticeable through the interviews below:

> *"We no longer do rainwater harvesting because we have already been connected to the PDAM network."* (Interviewee L12).

> *"Some collect rainwater, but it does not supply a significant amount of water. Moreover, since we have many buildings with asbestos roofs, we cannot guarantee the quality. I believe the water quality is awful due to dust pollution. It is not safe for drinking."* (Interviewee L15).

> *"The rainfall pattern is so uncertain. Sometimes it just rains for two days in a month. There was a time when it did not rain for months. I felt we were in a drought-like situation. Moreover, rainwater has a bit unpleasant taste since it falls on the roof. Rainwater is never used for consumption."* (Interviewee L21).

> *"Rainwater could not sufficiently supply our consumption. We must have at least three water containers, and they are not affordable. We could only afford to pay for water service from PDAM."* (Interviewee L26).

Figure 4.1.4.7 Rainwater Harvesting

Source: Courtesy of the Author (2024)

The spatial diversity of water sources in the coastal karst of Gunungkidul implies a variety of water service providers across the area. Figure 4.1.4.8 shows that 37% of coastal tourist destinations are served by either PDAM or SPAMDes, which source their water from underground rivers or water wells. Water kiosks account for 29%, followed by individual/communal wells and water trucks, which amount to 12%. Meanwhile, locally-based services and individual rainwater harvesting constitute the smallest two, six per cent and four per cent, respectively.

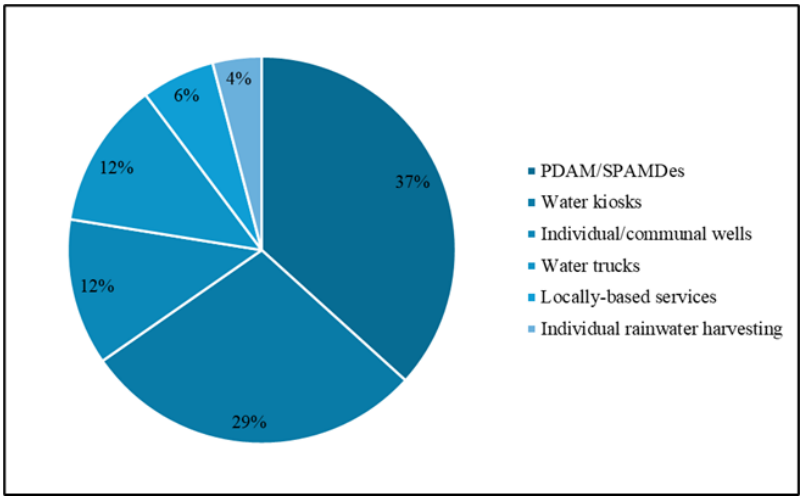


Figure 4.1.4.8 Proportion of Primary Water Provider in Gunungkidul Coastal Tourism

Source: Data Analysis (2025)

This distribution highlights a significant reliance on PDAM/SPAMDes for its established pipeline network. In general, these providers serve water of a similar

quality, which can be used for drinking and non-drinking water purposes. However, some beaches provide gallon/bottled water that they buy from water kiosks for drinking. Few beaches have established water wells (Figure 4.1.4.9) for meeting individual and communal water needs in tourism areas due to the absence of a water utility distribution network, such as in Siung Beach, Krakal Beach, and Gesing Beach.

> *"I have no water source that I built myself. Kiosks with bathrooms and toilets usually build their own bore wells independently, without government assistance. I have bathrooms, but for private use; thus, I do not make one. Therefore, I fortnightly buy from those who have them to supply my drinking water, bathrooms, and toilets."* (Interviewee L5: Local at Siung Beach).

> *"They are dug wells. We pool our money together to fund the installation. It can be quite expensive for us, ranging from 15 to 20 million Indonesian rupiahs for each well. There are up to 12 pumping machines installed in each water well we use, and every household has its own water containers."* (Interviewee L15).

> *"A military personnel member built a water well. I am unsure whether it is a dug or a bore well. He established the pipelines to deliver water to people in Gesing Beach. He invested in developing the system, supporting locals and tourism activities. There is only a water well here now."* (Interviewee L27).

(a) (b)

Figure 4.1.4.9 (a) Bore Well in Siung Beach, (b) Dug Well in Krakal Beach

Source: Courtesy of the Author (2024)

Water trucks are the most mobile providers, delivering water in various circumstances. Water trucks are the primary water delivery units for isolated beaches where the PDAM's network cannot or has not yet reached. Water trucks are consistently positioned near the water source (Figure 4.1.4.10) and serve customers across several beaches, such as Jungwok Beach, Wediombo Beach, and Watu Lumbung Beach.

> *"We buy from water trucks which source water from a distant natural spring, about five kilometres away. They deliver and store the water in each of our 5,000-litre storage tanks. Everyone has their water containers, particularly those who have bathroom and toilet services."* (Interviewee L1).

> *"We rely on Puring Source, the only water source in our area. It is on the right side of the road to Wediombo Beach. Water trucks serve water to our beach. The operators pump water from the concrete storage near the source into their tanks and travel to the beach to fill our water containers, which are connected to our own pipelines and taps in each kiosk."* (Interviewee L2).

> *"My supply is delivered by water trucks, which source their water from the Puring Source, a natural spring by the road heading here."* (Interviewee L4).

(a)

(b)

(c)

Figure 4.1.4.10 (a) Puring Source, (b) Concrete Water Storage, (c) Water Truck

Source: Courtesy of the Author (2024)

Water trucks serve as a complementary service on popular beaches when water demand rockets due to increased tourists, especially during weekends or peak seasons. People also rely on water trucks when the PDAM/SPAMDes service is temporarily inactive due to technical issues. Moreover, water trucks are deployed to supply areas where local water sources fluctuate seasonally.

> *"If the borewells underperform and the water flow recedes, there is no other option but to purchase water from the water trucks. We usually buy from the water trucks if we encounter emergencies such as borewells having trouble, and the dry season, as of now."* (Interviewee L5).

> *"SPAMDes works very well most of the time. Only in rarer instances does it take two or three days to serve due to damaged pipes. During this situation, I buy water from the water trucks, as do kiosks with bathrooms and toilets."* (Interviewee L10).

> *"Last year, the pumping machine was damaged five or six times. The water service had troubles last peak season, causing inconsistent flow and compelling us to ask for water trucks."* (Interviewee L11).

> *"SPAMDes is our main water provider. However, if it encounters some trouble whilst delivering the water, people will buy from the water trucks. Water trucks also supply those who do not have their pipelines connected to SPAMDes."* (Interviewee L14).

"From what I have seen from those who own these services, they do not merely use a single source from PDAM since it is not dependable. I think it can be dependable if the booster pumps perform well. Moreover, the water wells fluctuate throughout the year, decreasing during the dry season. Eventually, people will have their water fully supplied by water trucks." (Interviewee L15).

"The water trucks are nearby and very convenient. At the busiest time, I run out of water, so I buy from them. Also, during the lowest tides, the water well does not flow optimally, hence water trucks become my solution." (Interviewee L16).

"Our water supply is served by water trucks, run by the locals, which happen to utilise the same source as PDAM's. They both source water from the underground river near Ngobaran Beach to deliver water to the adjacent beaches, including Ngrenehan Beach. However, we are unable to subscribe to PDAM since we are not connected to their pipelines. Therefore, we use water trucks to supply the water containers in our kiosk." (Interviewee L23).

A few beaches have established an independent, locally-based water service, run by the people on the beach, due to their proximity to a local water source. Nampu Beach, Nglambor Beach, and Potunggal Beach manage to provide water from nearby sources to meet their water demand. In contrast to other destinations, people in Nampu Beach and Nglambor Beach do not have to pay to use the water (Interviewee L3 and Interviewee L6).

PDAM, SPAMDes, and water trucks are amongst the leading water service providers in terms of the size of their customers. Otherwise, locally-based services are usually free to access. The three aforementioned providers demonstrate differences in purchasing schemes and water tariff standards. PDAM and SPAMDes fundamentally apply a metered tariff that involves retrospective billing based on actual usage. Metered systems can generate higher revenue for utilities, as they allow for billing that more closely aligns with consumption trends, thereby supporting infrastructure and service improvements (Pihljak et al., 2021; Siddiquee & Ahamed, 2020). The tariff structure varies, for which PDAM implements a water tariff classification. Customers consuming their water for domestic or household demand will have a lower water tariff base compared to those using it for commercial or economic activities, as per the following interviews:

"PDAM applies a standard of a monthly fixed operational cost of 67,000 Indonesian rupiahs to cover water consumption of less than 10 cubic metres. A different rate will apply once consumption exceeds the predetermined thresholds, and the fixed operational cost is added to the total. In short, people pay 6,700 Indonesian rupiahs per cubic metre for water consumption of less than 10 cubic metres. Meanwhile, if they consume between 10 and 20 cubic metres of water, the water tariff increases to 9,000 Indonesian rupiahs. In other words, the tariff increases progressively with the water use. They also classify the type of consumers according to their activities, whether households or businesses, and they have their water tariff rules, respectively." (Interviewee L18).

"PDAM determines the water fee class according to consumer category. As we have a coastal tourism business, the water fee is higher than the water fee that applies to household water consumption." (Interviewee L24).

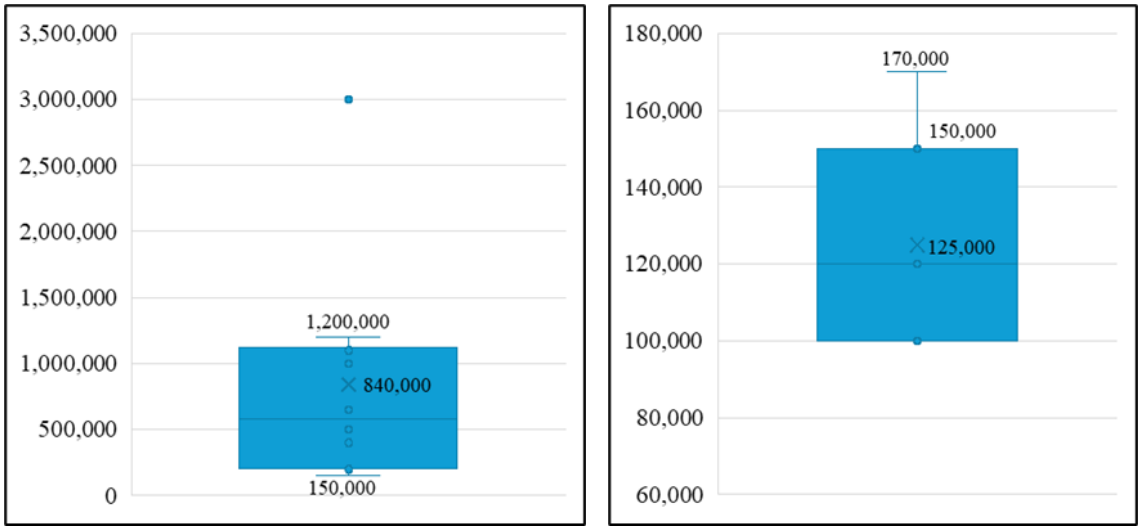
Meanwhile, the water trucks' tariffs vary depending on the accessibility, in terms of travel distance and the seasonal water variability.

"The tariff depends on the distance and accessibility. The less accessible road here leads to higher fees compared to Jungwok or Wediombo Beach. It is cheaper in the rainy season due to more water availability." (Interviewee L4).

"It is subject to the season and distance. In the rainy season, they deliver water to the beach for 150,000 Indonesian rupiahs per tank. Otherwise, they charge around 200,000 Indonesian rupiahs for the same tank size during the dry season. It can be expensive to buy water from the water trucks here since they travel a long way to reach the beach. It costs roughly 150,000 Indonesian rupiahs to buy water from them when you live in the village. However, you may have to pay up to 200,000 Indonesian rupiahs to make them deliver the water down to the beach. It also depends on how they collect the water." (Interviewee L27).

Figure 4.1.4.11 shows two box plots that illustrate and compare the water tariff between PDAM/SPAMDes and water trucks. Every month, people pay for the PDAM/SPAMDes service from 150,000 to 1,200,000 Indonesian rupiahs (approximately 7.6 to 61.4 pounds), with a monthly average of 840,000 Indonesian rupiahs (approximately 42.8 pounds). There is a beach with the highest spending at 3

million Indonesian rupiahs (approximately 152.8 pounds), due to having multiple facilities in operation. On average, people spend 125,000 Indonesian rupiahs (approximately 6.4 pounds) for every 5,000 litres, and they could buy water twice a week, especially during the peak season. This information reveals a higher water tariff pattern on beaches with reliance on water trucks.



(a) (b)

Figure 4.1.4.11 Water Tariff Comparison between (a) PDAM/SPAMDes and (b) Water Truck in the Coastal Tourism Zone of Gunungkidul Karst (in Indonesian rupiahs)

Source: Data Analysis (2025)

Across the coastal karst of Gunungkidul, more water sources are managed by these operators, whilst only a small part of the region, whose people utilise and access local sources independently. Figure 4.1.4.12 shows a topological map that illustrates the water distribution to every tourist destination in the coastal karst of Gunungkidul. This variety reflects the diverse landscape of water services in this region as a consequence of the convergence between natural constraints and tourism development.

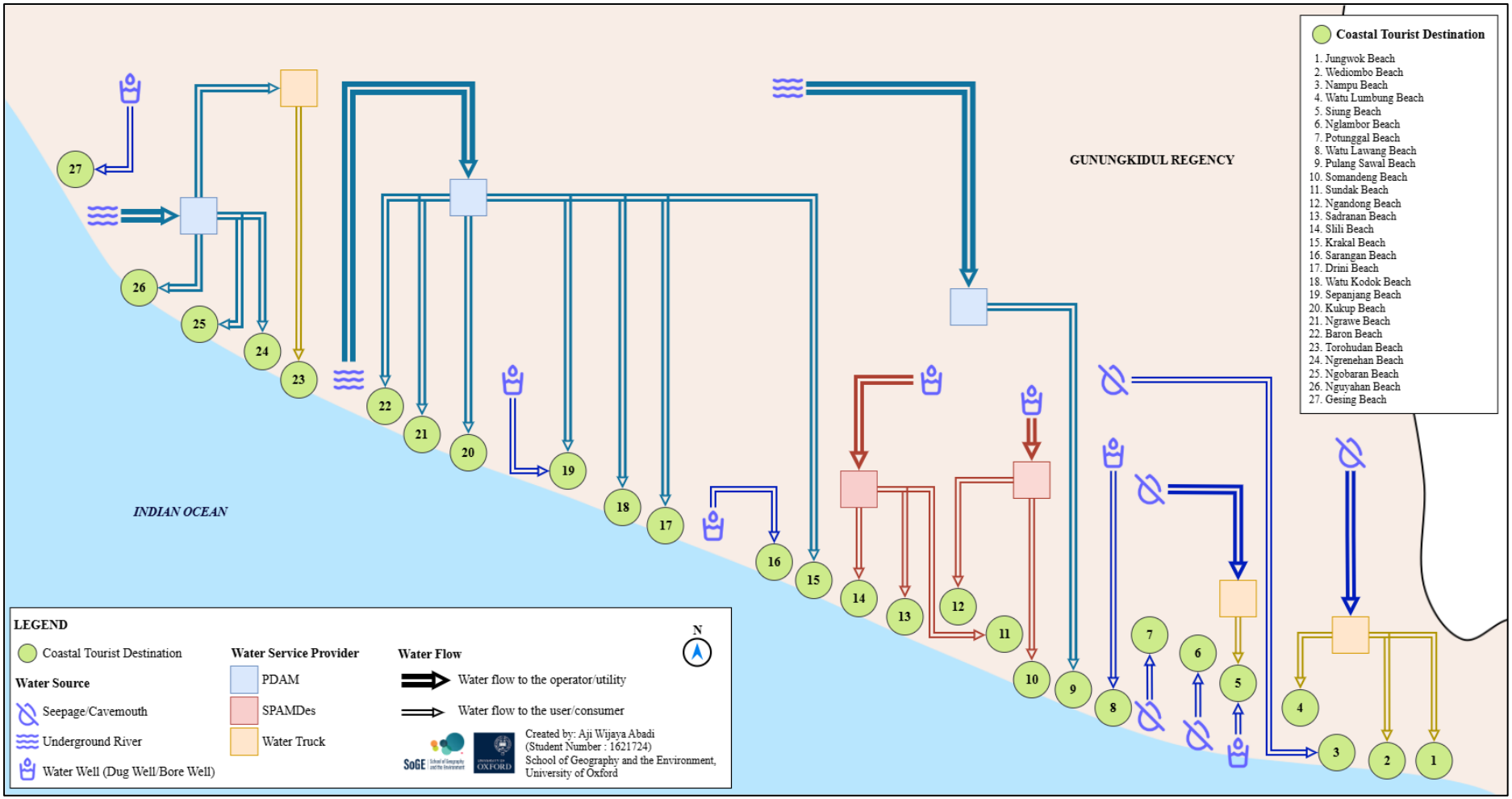


Figure 4.1.4.12 Map of Primary Water Service in the Coastal Tourism Zone of Gunungkidul Karst

Source: Data Analysis (2025)

PDAM stands out from other providers (SPAMDes and water trucks) because its water supply services extend across both the western and central parts of the coastal tourism zone (Tourism Strategic Zones 1, 2, and 3), allowing it to serve more coastal tourist destinations and ensure broader coverage. This area is within the Panggang sub-system and Bribin-Baron-Ngobaran sub-system, two hydrogeological units in Gunungkidul, where the flows are concentrated in the coastal karst zone. The abundance of groundwater accumulation there, reflected by the presence of major underground rivers, is a potential water source that further strengthens the capacity of PDAM to serve bigger populations or customers. The utility itself has received infrastructural aid from the Japanese government through the Japan International Cooperation Agency (JICA) to boost the water service since 2008, as highlighted by Interviewee G1, Interviewee L20, and Interviewee L22. Meanwhile, the eastern coast of Gunungkidul is further from the main underground rivers, potentially posing challenges to PDAM to expand its network. Therefore, many beaches in this part (Tourism Strategic Zone 5) rely more on local water sources, such as water wells or natural springs, operated by the community or through the SPAMDes programme and water trucks.

Instead of relying on a single uniform network, the coastal tourism zone in Gunungkidul karst operates through a complex mix of systems that have evolved to adapt to the region's natural and anthropogenic conditions. The interplay of the coastal karst landscape and tourism demand has shaped the overall water service, as illustrated by Figure 4.1.4.13. The flowchart indicates that PDAM is one of the most vital players in meeting tourism water demand. PDAM serves water for both drinking and non-drinking use, supported by SPAMDes as the community-based version of PDAM. Meanwhile, water trucks appear to be a water delivery service from multiple sources, including water wells, seepage/cavemouth, and even the PDAM's water. Additionally, for drinking water, people favour gallon/bottled water from the nearest water kiosks.

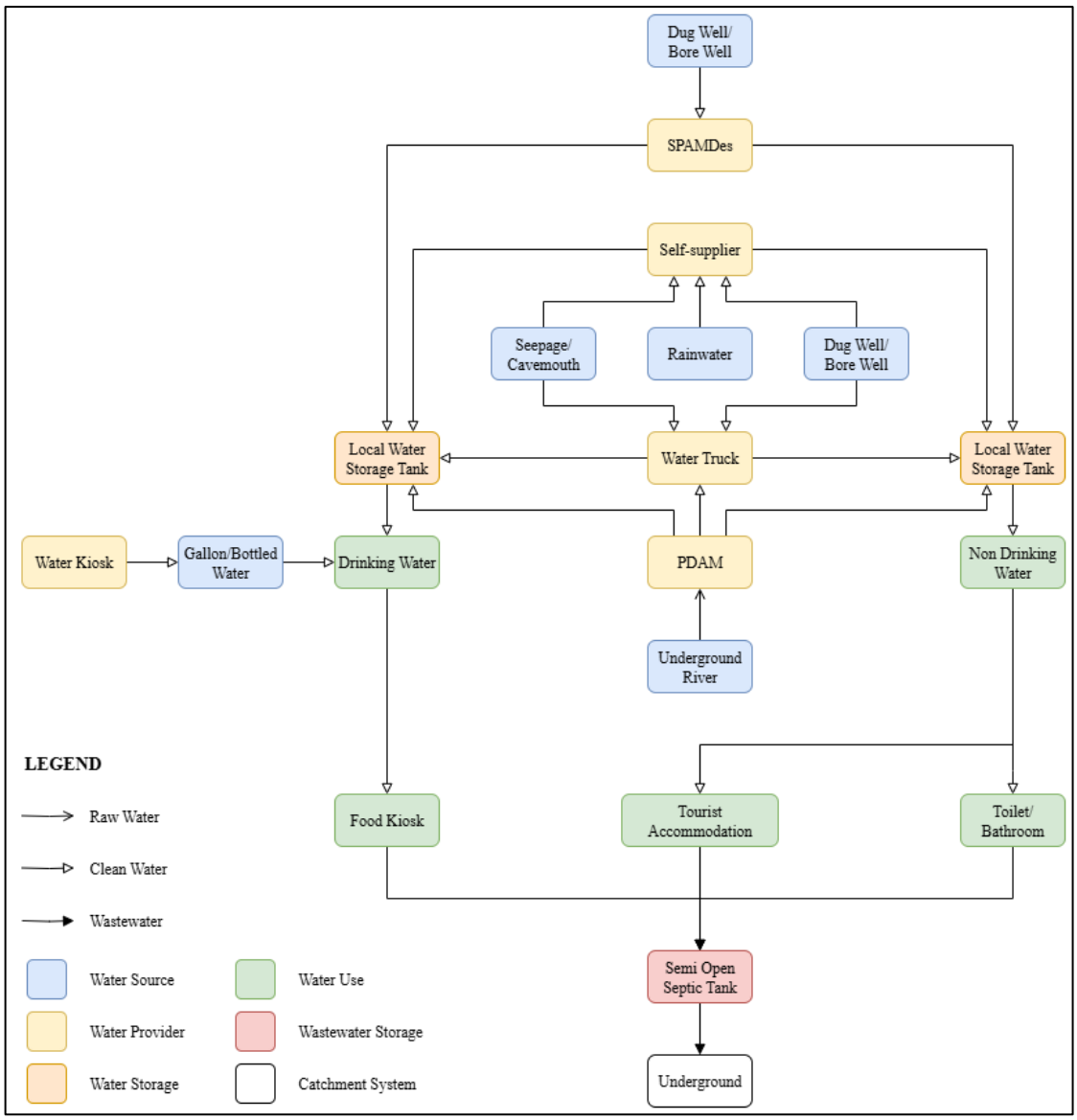


Figure 4.1.4.13 Water Service in the Coastal Tourism Zone of Gunungkidul Karst

Source: Data Analysis (2025)

In most coastal tourism areas, there is at least a primary water service accompanied by supporting services that complement each other to ensure overall functionality. A range of these options contributes to the sustained operation of the tourist attractions. Local vendors on the beach derive income by providing access to public water-related facilities, such as bathrooms and toilets, for which visitors are required to pay a usage fee. Interviews conducted at 27 beach sites uncovered notable variations in usage fees, primarily driven by differences in the pricing of water service. When a specific service is unavailable, alternative options are typically accessible, enabling local vendors to maintain access to water supplies and continue offering water-related services to tourists, sustaining their livelihoods. In addition, local vendors

may have strategies to conserve water during difficult times by incorporating individual storage tanks (Figure 4.1.4.14). For example, Interviewee L18 described how multiple water storage tanks in their kiosks were critical during peak demand:

> *"Two water-saving mechanisms are employed, with their application varying based on tourist volume. The system utilises a dual-branch pipeline; one line feeds directly into the kiosk taps, whilst the other channels water into large storage tanks. Due to pressure differences, where the PDAM water pressure exceeds that of storage tanks, I fill the tanks during peak seasons when demand is high. Once the tanks reach capacity, direct tap access is enabled, supported by PDAM's higher pressure. This approach not only ensures supply during periods of high demand but also provides a buffer in the event of temporary service disruptions. During periods of low demand, water is primarily drawn from the storage tanks, with minimal depletion, allowing for efficient resource use."* (Interviewee L18).

Figure 4.1.4.14 Water Storage Tanks

Source: Courtesy of the Author (2024)

4.1.5 Theme 5: Wastewater Management in Coastal Karst Tourism

The wastewater issue remains one of the tough discussions in Gunungkidul. Interviewee G4 affirmed that the lack of water flows on the surface river in the region makes it difficult to dispose of wastewater properly, exposing the surface water bodies to a higher risk of contamination. Concurrently, most people have individual wastewater disposal systems (SPAL) to store the wastewater underground (Interviewee

G3). This method has been practised by locals in coastal tourist destinations due to the permeability of the soil texture.

> *"As the ground is extremely sandy, it can allow the wastewater to flow downward."* (Interviewee L2).

> *"Because the ground is dominated by sandy texture, the wastewater can flow easily."* (Interviewee L11).

> *"Since the sand is quite good at absorbing and draining water, this space is never overfilled."* (Interviewee L17).

Unlike the intricacy of the water service system, the wastewater management system in the coastal tourism of Gunungkidul karst exhibits a relatively uncomplicated structure. Each food kiosk, public toilet, bathroom, and tourist accommodation has an identical on-site domestic wastewater disposal system. The interviews revealed that people separate the wastewater from the food kiosks and bathrooms or toilets, meaning each has a specific septic tank. This phenomenon is common on most beaches in the coastal Gunungkidul, although a few beaches have a more integrated and proper wastewater disposal design. The interviews also suggested that there are three types of local domestic wastewater disposal throughout the touristy coastline.

a. Direct Discharge

Siung Beach is amongst the beaches that directly discharge wastewater. Direct discharge means that wastewater produced by consumers' activities is released directly to the surface water bodies. Due to the unavailability of septic tanks on the beach, people in Siung Beach traditionally discharge wastewater to the adjacent surface water course (Figure 4.1.5.1).

> *"The wastewater from bathrooms and toilets is disposed of in the creek next to my kiosk. The small creek itself is not used for drinking or livestock farming. It has no flow in the dry season like this. In the rainy season, this creek flows and carries the wastewater to the ocean. Meanwhile, wastewater from the kitchen is stored in a specific container. We do not have septic tanks yet to store the wastewater."* (Interviewee L5).

Figure 4.1.5.1 Small River for Wastewater Disposal

Source: Courtesy of the Author (2024)

b. Individual Conventional Semi-Open Septic Tank

This type of septic tank is the most common design of wastewater disposal structure, found at 24 out of 27 beaches sampled. Figure 4.1.5.2 illustrates the cross-sectional feature of the septic tank. It has a simple concrete case connected to the disposal pipe, with no cover on its base to allow the wastewater to infiltrate. People place the septic tank two to three metres below the surface, or deeper. Not only do small-scale businesses use semi-open septic tanks, but larger tourist accommodation properties do too. One of the resorts on the Gunungkidul coast has applied this septic tank, as elaborated in the following interviews:

> *"We do not have a sophisticated facility to treat the waste, and we have not yet. So far, we have only discharged the grey water, including waste from the toilets and bathrooms, into the ground. We do not use an advanced system. We only dispose of them beneath in an underground space dug approximately 10 meters deep. This is like a vault, which has no impermeable seal at the bottom (semi-open septic tank). We have three of them, each for a specific wastewater."* (Interviewee P1).

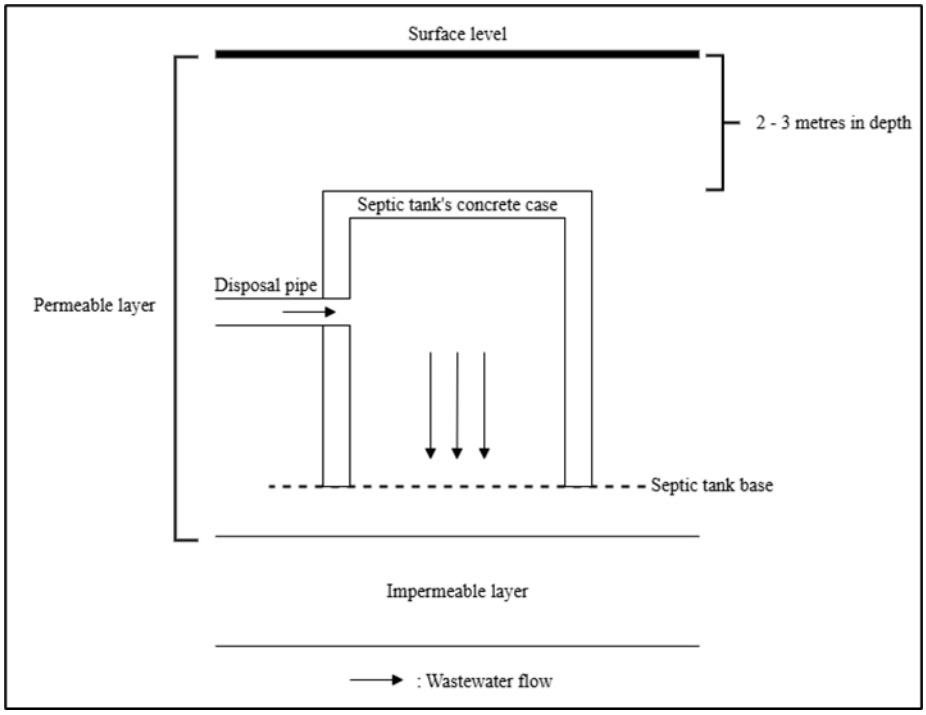


Figure 4.1.5.2 Cross-sectional Profile of Conventional Semi-Open Septic Tank

Source: Courtesy of the Author (2025)

Locals working on the beach are quite aware of the downside of a semi-open septic tank. Allowing untreated wastewater to flow subsurface potentially places the surrounding water sources at risk, especially in the area between the point of disposal and the coastline, conditional on the types of flows, whether a conduit flow or diffuse flow (Interviewee A1). Essentially, septic tank design incorporates factors to mitigate the associated impacts on local water sources, where applicable.

> *"We are certain of its safety as there is no local water source nearby. If there were sources, we would reconsider the wastewater disposal system, including the distance between it and the water table."* (Interviewee L18).

Up to this point, there is no concerning pollution in the coastal environment, as per the interview below:

> *"The seawater quality from each sampling point, especially for the E. Coli parameter, is far below the threshold. We have no concern about seawater contamination."* (Interviewee G4).

Nevertheless, one of the beaches, Ngrenehan Beach, has experienced difficulties in disposing of wastewater, despite no major water contamination having ever been recorded.

> *"However, the wastewater does not seem to infiltrate easily into the ground, somehow. I guess it has something to do with the soil materials, or there is a shallow water table. I assume the septic tanks here intersect with the interface zone of the sea surface. If I am not mistaken, there is an underground river beneath connected to some place over there. The river mouth appears on the sea."* (Interviewee L24).

The case in Ngrenehan Beach has demonstrated the shortcomings of a conventional semi-open septic tank. The disposed wastewater may have made contact with the unexplored water sources. Meanwhile, people in Sadranan Beach have developed an improvised version of a semi-open septic tank, one with an agitator, treating the wastewater before disposing of it. This demonstrates higher awareness of preventing water contamination.

> *"I use a two-step process for disposing of wastewater from bathrooms and toilets. First, it flows through an agitator septic system to break down solid particles within the wastewater, and then it flows into larger septic tanks. The septic tanks are semi-open, covered by a concrete base on their sides like a well to allow water to flow downward. I have had it since 2012, and it has not reached its capacity. Many people here ask me for advice about their septic tank systems. Some follow my guidance whilst others ignore it. For kitchen wastewater, we store it in different septic tanks with the same structure, covered by concrete on their sides."* (Interviewee L13).

c. Communal Wastewater Disposal System

According to the Regent of Gunungkidul Regulation Number 45 of 2011 on Wastewater Treatment (2021), this system constitutes a separate domestic wastewater processing facility, with a jointly centralised wastewater pipe network established for several households. Only a few beaches in coastal Gunungkidul have a communal wastewater disposal system, one of which is Drini Beach. The local government established this programme in Drini Beach.

"Previously, we worked with the public works and public housing office to make communal septic tanks in coastal areas." (Interviewee G3).

"I know there is one in Drini Beach because I have been in this office. If you walk near the local kiosks, you will notice the communal wastewater facility." (Interviewee G4).

Nonetheless, some people still discharge their wastewater into the river near Drini Beach, as captured by Figure 4.1.5.3. The appearance of the river's surface is covered in domestic waste and organic matter. This disparity also suggests that the wastewater system has yet to be inclusive.

Figure 4.1.5.3 Polluted River near Drini Beach

Source: Courtesy of the Author (2024)

Coastal karst landscapes are a challenging terrain in terms of their water availability. In Gunungkidul, tourist destinations has developed extensively along its coastal karst areas, and each exhibits a varying state of TALC, indicating heterogeneous scale and intensity that contribute to distinct water requirements and challenges. These areas remain under the scrutiny of the local government, which holds the major authority over water-tourism affairs, although no clear and strong framework directive to address them appropriately. The influence of government is seen in both technical and non-technical aspects. The environment office focuses on water conservation, whilst the RBO and PDAM influence more in water services. In the coastal tourism context, PDAM is the primary water provider for most

tourism zones, whilst a few destinations receive their supplies from small-scale and locally-based services such as water trucks. Consequently, the region exhibits heterogeneity in water services, including supply, accessibility, reliability, and affordability, which vary along the coastline. Meanwhile, no major wastewater issues have been reported despite conventional methods used for wastewater disposal, except for river pollution in Drini Beach. This case illustrates the breadth of certain water resource issues regarding the coastal tourism needs in all tourism zones.

The various options of water sources and water services available in this region have contributed to ensuring the continuous operation of coastal tourism activities. The system's inherent complexity, stemming from the involvement of multiple water service providers and dominant operators with differing capabilities, results in distinct challenges across different zones. The existing difficulties from this intricate water service landscape will be discussed in the next research question theme.

4.2 Present Challenges of Water Service in Coastal Tourism of Gunungkidul Karst (Research Question 2: What challenges threaten the water service operations for tourism in the Gunungkidul coasts?)

Within the socio-ecological framework of the water-tourism nexus, certain intrinsic and extrinsic factors continue to pose obstacles to the current water service system for tourism in the coastal karst of Gunungkidul. Intrinsic factors relate to the natural features of the coastal karst landscape, which influence hydrological responses and the dynamics of water resources in the area, including water availability and water-related risks. Likewise, water infrastructure is regarded as an internal factor that affects the reliability of the water supply. Conversely, extrinsic factors involve the impact of water demand, as well as water governance and institutions, on the existing water service landscape. The following paragraphs will outline several identified issues that tourism operators face in meeting water needs to sustain their businesses.

4.2.1 Theme 1: Internal Challenges

Topographical constraints appear to be the underlying challenge for developing an integrated water system in Gunungkidul. The scattered distribution of its massive groundwater resources makes it challenging to explore and establish a new system. Multiple stakeholders have mentioned this factor through several interviews as follows:

"We find it difficult to drill in the slopy land compared to plain, flat or lowland. We conducted one hard drilling in Semin for people who needed water, despite receiving a small flow rate. We assumed that sloping lands have less water storage; we should not drill in such a place again." (Interviewee G5).

"Actually, it is not that Gunungkidul has no water resources, but accessing the water there is one tough effort as all the water is beneath the ground surface and it needs highly skilled human resources, a lot of money, and more energy just to extract it from underground." (Interviewee N1).

"There could be increasing demand during the dry season, creating a long line of water trucks, hence the operators ask some of the water trucks to move to Pulejajar Source to reduce the burden on Puring Source. Nevertheless, water trucks are reluctant to go to Pulejajar Source due to the less accessible road." (Interviewee L2).

"We receive our water from an underground source that is distant and hardly accessible. It is between the mountain and the rice field, far from here. The water itself comes out from the cave system in the mountain." (Interviewee L3: Local at Nampu Beach).

A challenging mountainous landscape necessitates more sophisticated and improved infrastructure, as well as energy to maintain reliable service, a critical factor for PDAM as the main water provider in the studied area. However, the existing system adopted by the utility has yet to be fully capable. Moreover, when there is an electricity issue, the system is unable to pump water to higher grounds, which prevents other places or beaches from receiving water.

"The topographical factor has been a great issue for us as we need to gradually pump the water from the underground river to the water treatment plant, which requires loads of energy. A multi-staged water distribution network is an energy-intensive system. Also, some areas are too distant from the utility, so it takes a longer time for them to receive the water." (Interviewee G1).

"Electricity is one of the most common problems, hampering water distribution to customers. Additionally, the huge water containers used by the

PDAM as backup service are not necessarily situated at the highest altitude. Therefore, when a blackout occurs, water containers at the lower altitude are unable to pump water up to reach all the customers, and it will disrupt the water service if it happens in the dry season." (Interviewee L18).

The complicated contours are assumed to be a causal factor in the financial burden bear by PDAM.

"From the cost side, they need to spend on the distribution network and pumping the water to higher places, but most of the time, they do not have a high revenue. When PDAM distributes the water to highly accessible lowland or plain areas, they will benefit. Otherwise, the terrain of the southern part of the region is more challenging in terms of accessibility, but they must maintain the water tariff stable." (Interviewee A1).

Moreover, the proximity of coastal tourist destinations to the ocean has impacted the existing pipelines of PDAM and caused several technical problems. As some of the pipelines cross the coastal areas, they are vulnerable to tidal waves.

"Most likely are pipe leakages. It frequently happens, especially with pipelines along the coastline, where they become rusted or corroded due to seawater exposure." (Interviewee G1).

Local vendors on the beach are also aware that water quality issues influence their daily water use. People must boil, filter, and rest the water to separate it from the limestone minerals. As previously discussed, most water sources in the karst region are carbonate-bearing water. Meanwhile, the current water treatment plant (WTP) has not functioned optimally because it relies on downflow operation (Interviewee G1). This can lead to water filtration issues, and progressively, the mineral-rich water can deteriorate the pipelines, as mentioned below:

"It can clog our water taps and pipes because of limestone mineral precipitation if we are not committed to carefully cleaning them regularly. This precipitation can also be observed in our water containers and washing machines." (Interviewee L15).

During the rainy season, the PDAM service underperforms, resulting in longer water delivery as murky water requires more time in the treatment facility.

> *"However, its performance slows down every rainy season. The increased discharge of the underground river turns the water murky and requires more time for the filtration before being distributed to customers."* (Interviewee L19).

The resort management also opines that the water quality issue is more concerning. Interviewee P1 believes that the water from the utility is quite dependable in terms of volume, despite its high cloudiness.

Internal problems have been more frequently observed in the PDAM water service. Due to the infrastructure limitations of PDAM, people have faced difficulties in having reliable water delivery and better water quality. However, extrinsic factors can simultaneously stimulate water service issues, which will be discussed in the next point.

4.2.2 Theme 2: External Challenges

Within the scope of this study, at least three external challenges emerge as particularly distinct: climate-coastal interaction, suboptimal water governance mechanisms, and pressing tourism-related issues. Along with the intrinsic stressors, these extrinsic pressures have not only affected water availability and quality but have also disrupted the reliability of water service from various types of providers. Ironically, the complex interaction between these factors has disproportionately impacted the local vendors on the beach.

The local sources have encountered some problems, but water salinisation is the most concerning. Although research on climate change threats to the local water sources in coastal areas of Gunungkidul has been limited, it is possible that changing climatic conditions could exacerbate SLR and threaten coastal water sources through seawater intrusion. This intrusion leads to deterioration of groundwater quality, increasing salinity levels and affecting the potability and usability of groundwater (Rajaveni et al., 2016; Ranjbar et al., 2020). Underground rivers, seepages, or shallow groundwater wells are common along the Gunungkidul coastline and vulnerable to seawater intrusion across multiple temporal scales, which significantly disrupts the tourism activities, especially at the most popular destinations with high visitor traffic during the dry season. This phenomenon has been observed at some beaches, as identified through the interviews.

"Meanwhile, during the dry season, the underground river flow in the Bekah unit shrinks, allowing the seawater to invade the freshwater. Recently, we have had some work in the Bekah, and we found that the freshwater becomes brackish, so PDAM could not utilise it unless in the rainy season. In other words, PDAM should have an alternative source to shift from the underground river to adapt to the seasonal flow fluctuation." (Interviewee G5).

A worsening climate scenario could stimulate the impact of SLR on the coastal water sources. Some seepages and water wells located near the tidal zone, such as one in Nglambor Beach, Potunggal Beach, and Sepanjang Beach, have been affected by tidal fluctuations. Consequently, compromised water quality has restricted locals' access to drinking water. Instead, they use the brackish water for non-drinking purposes. From the water quality aspect, it suggests that the climate-coastal dynamics is one of the causal factors of deteriorated water quality.

"We can only pump the seepage, unless during the high tides. Obviously, the groundwater turns salty because of the high tides." (Interviewee L6).

"In the past, the tidal wave brought a lot of sand that clogged and temporarily sealed the seepage." (Interviewee L7).

This situation is affirmed by Interviewee A1, who highlighted the incidence of saltwater intrusion in several beaches.

"Seawater intrusion has occurred in some beaches such as Ngrenehan Beach and Ngobaran Beach, where people find the water is brackish as they drill water wells. It has also happened in Gesing Beach, especially the northwestern part of the coast, where they built tourist attractions, where we can find people experiencing the same issue." (Interviewee A1).

In terms of availability, different water sources exhibit varying responses from the rainy to the dry season. Most water sources managed by PDAM are quite sensitive to seasonal change, and water delivery may be unreliable. Some beaches even necessitate access to supplementary water services, such as water trucks or using their water wells. This situation could increase the risk of water scarcity, which occurs as peak demand typically coincides with the dry season. Similarly, locals also find that the water truck

services are delayed every dry season, due to a longer queue at the point of water collection. The following interviews provide the various experiences about the seasonal reliability of water services.

> *"In the last five years, we have observed a flow reduction in some water sources."* (Interviewee G5).

> *"We use more pumps to meet the water demand in coastal tourism. We will reduce it during the dry season when the underground river flow is low. Baron Beach has the largest underground river, constantly flowing throughout the year. Ngobaran Beach's underground river, however, recedes when the dry season arrives."* (Interviewee G1).

> *"In response to a seasonal water scarcity, particularly during the dry season, the operator responsible for the Pulejajar Source may consider granting temporary access to water trucks designated for Puring Source so the coastal people can maintain their tourism water supply."* (Interviewee L2)

> *"Water trucks will not use water sources on the beach because their quantity decreases during the dry season. It would be difficult, especially when most beaches were packed with tourists."* (Interviewee L15).

> *"I still use my water well to meet water demand for tourists. Most people here use water wells because they find that the PDAM service is not reliable for them."* (Interviewee L16).

Furthermore, the uneven and unreliable water supply along the coast of Gunungkidul is linked to the unintegrated water supply system and lack of coordination amongst the relevant stakeholders. The interviews with government entities revealed that some maintain limited collaborative relationships; however, there is no overarching framework to support comprehensive, well-coordinated, and coherent cooperation involving all stakeholders. The interviews with Interviewees G1, G2, G3, G4, and G5 showed no evidence of specific and technical guidance for sustainable and climate-resilient water management in the coastal karst tourism zone in Gunungkidul. The current RPPLH does not consider climate change projections and impacts, and the government has not established regulatory measures to protect water sources, ensure

water access, or manage wastewater, as it perceives no immediate crisis requiring intervention (Interviewee G3).

Each government body tends to focus narrowly on its own responsibilities, making it difficult to address broader, cross-cutting issues or to work collectively towards shared goals. For instance, the tourism office's Regional Law of Gunungkidul Regency Number 8 of 2020 on Amendment of Regional Law of Gunungkidul Regency Number 3 of 2014 on Masterplan of Gunungkidul Regency Regional Tourism Development of 2014 – 2025 contains no provision on the water resource management in the strategic tourism zone, resulting in a lack of alignment with the water conservation efforts of the environment office. Meanwhile, PDAM has no specific conservation procedures for its water sources. These issues reflect a reactive rather than proactive governance approach, potentially leaving critical situations unaddressed, such as the current water supply capacity lagging behind the growth of coastal tourism, resulting in discrepancies in water service performance and reliability.

Additionally, the current water system faces significant financial constraints, which restrict efforts to optimise and improve water utilisation. Furthermore, the absence of a comprehensive framework, infrastructure, and institutional support limits the community's ability to act as a self-sustaining entity in supplying its water needs. Ultimately, this impacts the system's capacity to deliver water consistently and reliably, especially during peak seasons.

> *"PDAM bears more burden in terms of financing."* (Interviewee A1).

> *"Our water treatment plant is incapable of fully operating when the water demand goes up extremely during holidays. Otherwise, we tend to reduce the production."* (Interviewee G1).

> *"We utilise deeper groundwater and underground rivers for our water consumption, but we have not optimised them due to technical and financial factors for operational."* (Interviewee G2).

> *"I want to emphasise that we have a lot of water sources scattered in this area. However, our community receives minimal or no support from governmental authorities in terms of access, management, or infrastructure development."* (Interviewee L5).

"The regency government has not allocated anything to this beach. We already proposed to the corresponding office for installing electrical infrastructure to facilitate a water distribution network to this beach, but we have not seen any response. I doubt it will be realised soon. The village government funding is limited to supporting a single coastal development programme per year, using their local own-source revenue. Meanwhile, the corresponding offices do not necessarily allocate a budget to us every year. Every program we have established here is solely powered by the revenue generated from coastal tourism activities." (Interviewee L23).

Following this, the current pricing structure appears inequitable, as users are charged despite receiving an inconsistent water supply. It leads to questioning water affordability because users tend to pay more for alternative sources or supporting facilities, which evolves into a financial burden.

"We could try to build a water well for the water supply. However, we do not have the experience in water treatment. In addition, the costly installation could put us in another financial burden." (Interviewee L26).

"There was a potential site to extract the water at 20 meters depth. Once we drilled the ground, there was just a small amount of water at that depth. Going deeper, we lost the water flow. It turned out to be a failure, and unfortunately, it took us 80 million Indonesian rupiahs." (Interviewee L27).

The tourism office outlines ambitious goals in its tourism plan, which are not aligned with the current infrastructure, including water service. Tourism businesses and private actors have increasingly established their presence along the coastline for tourism development, putting additional pressure on the limited water supply. Interviewee N1 highlighted signs of deviation from the spatial plan, as some agricultural lands initially designated in the RTRW were converted into tourism sites, and many resorts in Gunungkidul were constructed in areas that do not conform to the plan. Interviewee N1 further mentioned that the reputation of Gunungkidul's difficult water access and unproductive agricultural land has encouraged tourism development.

"I assume SPAMDes has something to do with the temporary disruption in water service every afternoon during the holiday. It may stem from technical

issues; however, its recurring pattern during peak demand periods raises concerns that it could also serve as an informal mechanism to control or restrict water usage. It is chaotic when many tourists on the beach demand water, but the water service is unavailable momentarily every day when they need it the most. I had no choice but to buy another water container to secure my water supply." (Interviewee L14).

"When the holiday season arrives, we receive a lot of visitors, yet sadly, the water supply may not be available the entire time throughout the season. For instance, the water continuously flows from night to morning. Otherwise, we are unable to access it in the afternoon since the water flow is not constant." (Interviewee L17).

"The water supply from PDAM is stable, but because of the higher demand during the peak season, they have to divide the flow, so people receive a smaller supply. At the same time, PDAM has a lot of customers. Consequently, people have to wait longer to receive the water due to the slower utility performance. It flows, but the water flow we have on our taps is smaller than on a typical day." (Interviewee L19).

The development of tourism has also sparked social tension, as some investors have attempted to take over beach areas and displace the locals, who were expected to benefit from it. Such dynamics could intensify competition for water resources between local communities and external entities, as seen on Bali Island, which has faced water disputes and competition between households and tourism actors, according to multiple studies by Hornbacher (2021), Saraswaty (2024), Strauß (2011), and Yamamoto et al. (2021). It is important to note that the land in question is part of the Sultan Ground and has been officially designated by the Sultan for the benefit of the local population, ensuring their continued access and use as a means of supporting their livelihoods and long-term prosperity.

"Investors have tried to force the locals to relocate from the adjacent beach, Sanglen Beach. There were 30 people displaced, so the Sultan closed the beach, which just happened recently." (Interviewee L18).

The present challenges within the water services for coastal tourism in Gunungkidul karst are caused by both intrinsic and extrinsic factors. The karst terrain inherently leads to cloudy water, which is highlighted by many local vendors on the beach, regardless of the types of water suppliers. Locals find PDAM and SPAMDes are not dependable due to infrastructure issues, which lead to higher reliance on water trucks in some destinations, especially during peak demand periods. Meanwhile, amongst external threats, salinisation poses greater risks as most major water sources are located in coastal areas and could intensify following climate change. Moreover, the water-tourism governance in the region is not fully capable of effectively addressing the above issues due to weak institutional frameworks, unclear coordination, and insufficient funding, overshadowed by tourism expansion.

The rapid growth of coastal tourism indicates an upcoming increase in water demand for tourism. This significant and ongoing change impacts the entire water service system, which is complex and sensitive to both internal and external pressures. Given the anecdotal evidence and the government's plan to develop more coastal tourist destinations, the issues discussed require tailored interventions to promote sustainable and responsible water service practice in coastal tourism. The next subsection will outline the stakeholders' proposed plans and examine how these plans should be implemented or improved.

4.3 Addressing the Current Water Issues of Coastal Tourism in Gunungkidul Karst (Research Question 3: In what ways do the corresponding stakeholders effectively address the present challenges to enhance future planning and implementation?)

As an emerging tourism zone, the coastal karst of Gunungkidul continues to struggle with barriers that hinder water services. Despite efforts invested in the existing water service system, intrinsic and extrinsic constraints in this transitional environment persistently impact locals' ability to source, utilise, consume, and manage water in their tourism areas. Interviews with locals highlight key challenges in the current water service, including unreliable main supply, underdeveloped backup systems, and the lack of a strong institutional and policy framework needed to support and sustain effective operations.

4.3.1 Theme 1: Technical Interventions

One of the key indicators that determines improved water supply reliability is the performance of the water infrastructure (Charles et al., 2022). The current PDAM infrastructure does not adequately support the requirements of the entire study area,

resulting in significant spatial disparities in coverage. This existing gap is further compounded by the lack of a complementary water service system, arising from multiple issues caused by both internal and external factors, such as challenging terrain, ineffective governance, and varying community capacities, which are overshadowed by the potential for tourism expansion.

As the leading water provider in the region, PDAM has prioritised the infrastructural projects to enhance its service. Interviewee G1 mentioned the urgent need to increase capacity by transitioning to larger pipelines to prevent operational losses. PDAM also plans to construct a new WTP to improve the efficiency and consistency of water distribution.

> *"We are preparing for a new WTP on the highest point in Baron Beach. The project is expected to be completed by 2025 or 2026; however, we are currently in the process of identifying a suitable location for the facility. Once it is finished, we will reduce the operations of the former WTP. Our current WTP has not been optimal because it merely applies a downflow technique. Subsequently, the water supply will be primarily supported by the new WTP, which will continue to utilise the same underground river at Baron Beach."* (Interviewee G1).

> *"I heard a large water reservoir is planned for Ngrawe Beach to support the existing system, which still relies on booster pumps. Positioned at the highest elevation, it will enable gravity-based distribution to coastal communities, including Kemiri Village and several surrounding sub-districts, with minimal energy use."* (Interviewee L20).

According to Interviewee G1, the new WTP will incorporate honeycomb media in its sedimentation unit to enhance performance and efficiently lower costs. The use of honeycomb biofilters in Surabaya's water utility has improved raw water quality by effectively removing natural organic contaminants and reducing turbidity (Said et al., 2025). This approach is suitable for karst groundwater, which requires treatment to reduce cloudiness and murkiness, especially during the rainy season. Using honeycomb media also offers benefits in simplicity, affordability in operational and maintenance costs, and high efficiency in water quality improvement (Said et al., 2025).

The utility should develop a strategic protection plan for existing water sources, with emphasis on coastal subterranean rivers, such as the one in Bekah, which already

shows signs of seawater intrusion. These systems are particularly vulnerable to salinisation caused by SLR, especially during low-flow periods when diminished freshwater discharge weakens their natural defence against marine encroachment. Interviewee G5 considered applying a moving weir to prevent seawater from entering the freshwater and anticipated that PDAM would seek alternative water sources to support supply during dry periods.

The challenging topography remains a persistent obstacle to constructing a new distribution line connected to the existing infrastructure. Alternative options, such as utilising nearby sources, as the one in Siung Beach, an untapped resource near Sundak Beach, or drilling water wells, could be considered. Nevertheless, these possibilities are challenged by financial constraints.

> *"It may be worthwhile to consider planning for the use of Sundak Source to serve this area. Its abundant supply makes it a viable option, and it could serve as a backup in case of temporary disruptions to the main system."* (Interviewee L11).

> *"Water wells can be more affordable. Despite their high initial cost, we can save a lot because they require minimal maintenance. We just install a small water pumping machine to operate it."* (Interviewee L26).

Small-scale systems, such as SPAMDes, communal water wells, or solar-powered reverse osmosis water kiosks previously run by local vendors at Sepanjang Beach, or more advanced technologies such as the former desalination plant at Gesing Beach, also present potential solutions. However, the discontinuation of these earlier initiatives highlighted concerns about long-term feasibility, institutional support, and financial sustainability. Reviving such systems would require addressing these structural issues.

> *"Gesing Beach once had a water well near the fish market, but it suffered from high salinity due to seawater intrusion. To address this, a small-scale desalination unit was introduced, producing drinkable water and sea salt as a by-product. However, due to low profitability and limited community interest, especially compared to the tourism sector, the project was short-lived."* (Interviewee G4).

"We aim for more water wells, but limited financial capacity makes it challenging, even adding one is difficult. Currently, communities share wells; for example, 30 households in this area rely on just four." (Interviewee L15).

"We used to have a reverse osmosis installation, powered by a solar panel, to supply drinking water from the water wells. This project was launched in 2014 or 2015 near Sepanjang Bus Station and managed by the village government. Sadly, this facility only survived for three years as the gallon water price was too cheap to create a high economic benefit to the locals." (Interviewee L19).

Additionally, rainwater harvesting is a feasible, low-cost, and underutilised solution for supplementing local water supplies. Whilst the government previously initiated efforts, they were not sustained. Reviving and institutionalising such a system is critical for reducing water stress, especially during peak demand periods.

"We initiated a standardised artificial aquifer programme for rainwater storage (ABSAH). The system uses layered, safe materials to filter and store rainwater in designated structures. Its implementation depends primarily on the availability of land. This approach prevents rainwater loss; supplies water for domestic use and allows for further treatment to meet potable standards." (Interviewee G5).

Since funding remains the major obstacle, exploring innovative financing options such as public-private partnerships (PPPs) or blended finance will be crucial for supporting future water infrastructure development. However, implementing PPPs for water supply projects in Indonesia often faces several challenges, including land acquisition, water source availability, inflation, tariff mechanisms, and downstream infrastructure establishment, which delay the project completion, highlighting the need for coordinated efforts amongst all involved stakeholders (Auliya et al., 2023). With ongoing difficulties and weak governance in Gunungkidul, strengthening institutional foundations is essential for successful PPPs. Although the interviews have not shown any progress towards establishing PPPs, one of the few resort owners has helped meet local water needs.

"The well water is shared with surrounding households to support better living conditions, mainly for bathing and washing. Each month, we provide two

5,000-litre water containers to help meet local demand. Aware of our presence here, we are committed to giving back to the community." (Interviewee P1).

4.3.2 Theme 2: Non-Technical Interventions

Amidst demanding technical interventions, non-technical ones are equally necessary and often play a vital role in achieving holistic success. Non-technical dimensions include both control and management of the water service system and consumer behaviours. Initiatives in these areas are crucial for providing equitable and sustainable water use, particularly in regions where water competition is intense.

The most important work to be undertaken is improving the foundational reforms of the existing water-tourism governance. Currently, stakeholders lack strong coordination and a clear framework to guide collective action towards integrated solutions. Government stakeholders tend to prioritise their specific responsibilities, leading to siloed approaches and insufficient cooperation in addressing water-related issues in water-scarce regions such as Gunungkidul, which has a significant collective water demand.

Overlooked key aspects, such as climate change threats, integrating water resources management schemes in tourism plans, and fostering community building, must be considered to develop a holistic and responsive framework for implementing water-secure tourism policies. Additionally, past water scarcity and drought events can inform the development of effective countermeasures, helping to better prepare for future challenges amidst increasingly complex water demands from domestic use, tourism, and agriculture. Grecksch & Landström, (2021) emphasised that pursuing sustainable governance necessitates a firm commitment to address these fundamental dimensions: uncertainty and flexibility, tailor-made approaches, and public participation. These components highlight areas within current governance structures needing enhancement.

Firstly, access to the latest research will be vital for more responsive and relevant evidence-based policymaking. Topics such as climate change impacts, tourism demand management, or potential aquifer contaminations from seawater intrusion have received limited scholarly attention, as per Interviewee A1. These areas require further empirical investigation to bridge the existing knowledge gap. For instance, a predictive water consumption model that accurately guides water resource planning and socio-economic development (Yang et al., 2023). In Gunungkidul, this could help develop a water

resource management plan adopting an integrated approach to allocate water for agriculture, industry, and tourism without triggering water insecurity. As a result, stakeholders would have a greater adaptive capacity to manage uncertainty with appropriate measures.

Secondly, adapting governance to local contexts is crucial to ensure that the policies meet the needs of those affected and operate effectively. A one-size-fits-all approach remains a barrier to policy feasibility (Griffiths, 2017). This issue is evident in the disparities in water service fees amongst providers. In this study, the water service inequality by PDAM has influenced affordability at several beaches, yet the water pricing mechanism appears disadvantageous for small vendors in tourism areas. Furthermore, the inconsistency of PDAM and SPAMDes tariffs between peak and off-peak seasons, as well as between rainy and dry seasons, has increasingly burdened beaches with limited local water sources, infrastructures, and visitors. One possible solution is to reconfigure fairer water pricing standards tailored to the local conditions and the development level of the tourism industry. Water pricing should also consider public acceptance, in which pro-poor policies that aim not only to limit water demand, but also maximise water revenue (Zetland, 2021). The following interview suggests implementing different pricing reflective of the scale of the businesses.

> *"In my opinion, tourism actors should contribute more and have higher responsibility through some mechanisms to ensure that all tourism businesses in the coastal zone consume water responsibly. I have no idea whether PDAM applies a specific tariff to them. But it is noteworthy that the larger the business, the more it consumes water and acquires revenue, especially during the holiday season. So, I assume PDAM could control their water consumption accordingly."* (Interviewee A1).

Thirdly, the contribution to the community is significant to the water-tourism governance. Despite insufficient coordinated community empowerment, a few stakeholders have engaged with local communities to cope with water service disparities. For example, an NGO in the region has assisted with training to locate a water source, aiming for self-sufficiency.

> *"We are working in Jepitu currently to establish a community-based water utility. We provide Geographic Information System (GIS) training to locals to*

map potential water sources and plan to establish a cooperative to manage operations and ensure community benefits. To address water scarcity caused by limited surface water in Gunungkidul, we aim to utilise groundwater through an initiated participatory approach." (Interviewee N1).

The environment office has taken one step closer to empowering the local community by recognising and institutionalising the local wisdom as a climate change mitigation and adaptation strategy in the region.

"We support the local community in recognising and formalising their existing climate change mitigation and adaptation practices. By registering these activities in the Ministry of Environment's National Registry System (SRN), we help legitimise their contributions to resilience. This aligns with our ongoing commitment following the ratification of the Paris Agreement. The platform also enables access to awards or incentives, depending on the nature of the activities." (Interviewee G4).

Solving water issues in the coastal tourism of Gunungkidul karst requires technical and non-technical approaches. PDAM is committed to providing more reliable water supplies by enhancing its facilities. PDAM plans to build a new WTP that incorporates honeycomb filtration structures and renew its pipelines. The region may also reintroduce previously initiated water projects, such as rainwater harvesting systems or small-scale desalination units, apart from utilising untapped local sources. In addition, the pricing structure should be reconfigured to align with the level of service, performance delivered, and scale of business, thereby achieving a fairer fee system. To enable this, the region must have stronger institutional arrangements that facilitate improvements, including research and development of climate change influence, water project financing, and public participation.

Addressing the water-tourism issues in the region requires strong commitment from the involved stakeholders. The region faces an urgent need to improve its water infrastructure to enhance performance and reliability across many circumstances. Whilst technical interventions are important, non-technical measures are more foundational in enabling and sustaining the implementation. Through a firm and effective framework, the technical solutions can be facilitated and guaranteed without compromising the interests of specific groups or sectors.

SECTION V
CONCLUSION

5.1 Summary

The coastal tourism zone of Gunungkidul karst features a diverse range of water service landscapes. Uneven distribution of water sources across various coastal tourism zones and fluctuations in water demand related to tourism development stages have shaped water service availability in each coastal tourist destination. Most of the region relies on multiple sources for two main reasons: either due to the absence of alternative sources or a preference for certain sources for specific water uses, especially drinking water. Unfortunately, several beaches are reliant on a single source as no other options are available.

PDAM is the leading water service provider in coastal Gunungkidul, mainly in the western and central tourism zones (Zones 1 to 3), where tourism activities are steadily expanding. Meanwhile, coastal communities in the eastern tourism zone (Zone 5) rely on self-supply services and water trucks that draw from surrounding local sources. Water trucks have become an alternative in areas with limited access to water sources and a backup, especially during peak demand and dry seasons when water scarcity is more likely. Fees for water services differ by provider, season, or location. PDAM and SPAMDes charge their customers via metered tariffs, but many complain about their reliability. Tariffs for water trucks may vary slightly throughout the year, depending on demand and travel distance, making water trucks a less affordable choice for local tourism vendors. Water affordability directly impairs business, as coastal tourism relies heavily on water services and facilities.

Inequitable water services in Gunungkidul's coastal tourism zone are caused by both inherent and external factors. The karst landscape and the current water infrastructure profile have limited service providers' capacity to deliver a consistently reliable supply to all destinations. External pressures can worsen the ongoing issues with the water supply. Weaknesses in water-tourism governance, financing, and institutional support have hindered local communities' ability to develop self-sufficient, localised systems as alternatives to the main services. Additionally, environmental threats from climate change and increasing tourism demand remain underexplored, posing further challenges to providing sustainable water services.

Addressing these problems requires both technical and non-technical measures. The complex nature of the coastal karst environment and tourism needs makes adopting a single solution difficult. The government plans to construct another WTP and optimise current

distribution networks, but successful implementation also depends on good governance. As a result, stakeholders must collaborate to overhaul and strengthen existing siloed governance between the water and tourism sectors, including participatory engagement within the region and exploring innovative funding options.

5.2 Recommendation

This research successfully spans an extensive scope within a highly complex landscape system. Whilst many previous works in the region have selected a specific tourist destination, this study encompasses the entire coastal tourism zone with a sample of 30 sites, providing detailed information to understand the linkages between water and tourism, which have been disproportionately addressed in past research. The study also offers a holistic perspective as it involves multistakeholder approaches.

The application of thematic analysis and spatial analysis in this research serves as a powerful approach that effectively facilitates the research questions. Employing thematic analysis offers rich information derived, helping to understand more nuanced issues in the water-tourism nexus. Thematic analysis provides a guide to context-based problems happening in the water service of coastal karst tourism in Gunungkidul. Moreover, with the spatial analysis employed, this research successfully depicts the spatial inequality within the studied area, providing insights into the geographic distribution of water-tourism issues. Both approaches successfully disentangled the intricacies of two different themes, water and tourism, in a complex environment, the coastal karst zone.

Pragmatically, the research also contributes to broadening the horizons of knowledge in understudied areas such as coastal karst and tourism, especially in developing nations. Developing countries face multifaceted water-tourism issues, partly due to a lack of comprehensive research. This study minimises the knowledge gap amongst stakeholders who are involved in the water and tourism sectors, thereby raising awareness and strengthening the knowledge base of stakeholders that enable better-informed policy and management decisions. This research would offer greater contributions with improved accuracy and the application of more advanced methods, which are briefly discussed in the following paragraphs.

The presence of water service is crucial for sustainable coastal tourism operations. This research has shown that a specific sector, tourism, also significantly influences water use. Coastal tourism plays a vital systemic role due to its capacity to both cause and respond to water-related crises. However, coastal tourism is not the only sector in the coastal karst of

Gunungkidul. It is also important to consider other sectors, such as households, agriculture, and mining, which also consume substantial amounts of water each year. Understanding water use dynamics across multiple sectors will provide a broader perspective on their interconnections and whether a sector's activities impact others, as well as highlight differences in water service performance and reliability amongst sectors.

The qualitative approach used in this study has helped to interpret anecdotal experiences and contextual views, offering an in-depth understanding of complex phenomena. This study has thoroughly demonstrated the variance, dependence, and perceptions of water service in coastal Gunungkidul, achieved through multistakeholder engagement. However, the absence of quantitative methods should be addressed in future research to empirically triangulate the qualitative data, enhancing its reliability and validity. Technical aspects such as water balance equations, tourist statistics, and environmental risk assessment could be incorporated, including considerations of water financing or tourism revenue.

Due to logistical constraints and safety concerns, the study was conducted during the dry season, and no data were collected in the rainy season. This limitation may restrict understanding of interseasonal variability, despite it being addressed in the interview guidelines. Consequently, it might result in an incomplete picture of annual coastal tourism dynamics, including water use patterns and user behaviour. Therefore, follow-up research involving data collection during the rainy season is essential to deepen and strengthen the findings.

REFERENCES

Agoubi, B., Kharroubi, A., & Abida, H. (2013). Saltwater intrusion modelling in Jorf coastal aquifer, South-eastern Tunisia: Geochemical, geoelectrical and geostatistical application. *Hydrological Processes*, *27*(8), 1191–1199. https://doi.org/10.1002/hyp.9207

Ahdiyana, M., Pambudi, A., Widianto, H. W., & Agustanta, N. (2025). Pro-poor Policy in Community-Based Drinking Water and Sanitation Program in Gunungkidul Regency. *Proceedings of the International Joint Conference on Arts and Humanities 2024 (IJCAH 2024)*, 1663–1674. https://doi.org/10.2991/978-2-38476-317-7_158

Aji, R. R. (2019). Komponen pariwisata pantai dalam ekonomi wilayah Kabupaten Gunungkidul. *ETHOS (Jurnal Penelitian Dan Pengabdian Kepada Masyarakat)*, *8*(1), 9–15. https://doi.org/10.29313/ethos.v7i2.4412

Allocca, V., Manna, F., & De Vita, P. (2014). Estimating annual groundwater recharge coefficient for karst aquifers of the southern Apennines (Italy). *Hydrology and Earth System Sciences*, *18*(2), 803–817. https://doi.org/10.5194/hess-18-803-2014

Andayani, K. W., Winaya, I. N. A. P., Triadi, I. N. S., & Wardana, I. G. N. K. M. A. (2023). The study of clean water supply system managed by the community to ensure reliability of the clean water supply system in Tabanan District. *International Research Journal of Engineering, IT & Scientific Research*, *9*(2), 65–75. https://doi.org/10.21744/irjeis.v9n2.2289

Anggraeni, T., Putra, D. P. E., & Taufiq, A. (2023). Groundwater Quantity and Quality of Springs of Karst Region in Pacitan Regency, East Java. *Proceedings of the International Conference on Sustainable Environment, Agriculture and Tourism (ICOSEAT 2022)*, *26*. https://doi.org/10.2991/978-94-6463-086-2_47

Anirban, B. (2020). Trends in global coastal tourism development and its eventuality in the era of climate change. *Disaster Advances*, *13*(9), 17–25. https://www.researchgate.net/publication/371043537

Arabadzhyan, A., Figini, P., García, C., González, M. M., Lam-González, Y. E., & León, C. J. (2021). Climate change, coastal tourism, and impact chains–a literature review. *Current Issues in Tourism*, *24*(16), 2233–2268. https://doi.org/10.1080/13683500.2020.1825351

Arahuetes, A., & Villar, R. (2017). Desalination, a strategic and controversial resource in Spain. *WIT Transactions on Ecology and the Environment*, *216*, 61–72. https://doi.org/10.2495/WS170061

Athanasopoulou, A. (2013). *Tourism as A Driver of Economic Growth and Development in the EU-27 and ASEAN regions*.

Auliya, R. R., Nurkholis, N., & Sabirin, M. T. (2023). Public-private partnership water supply project in Indonesia. *International Journal of Business, Economics & Management*, *6*(2), 214–222. https://doi.org/10.21744/ijbem.v6n2.2150

Badan Meteorologi, K. dan G. (2021). *Peta Rata-Rata Curah Hujan dan Hari Hujan Periode 1991 - 2020 Indonesia*. Pusat Informasi Perubahan Iklim BMKG.

Bakalowicz, M. (2018). Coastal karst groundwater in the Mediterranean: A resource to be preferably exploited onshore, not from karst submarine springs. *Geosciences (Switzerland)*, *8*(7). https://doi.org/10.3390/geosciences8070258

Baños, C. J., Hernández, M., Rico, A. M., & Olcina, J. (2019). The hydrosocial cycle in coastal tourist destinations in Alicante, Spain: Increasing resilience to drought. *Sustainability (Switzerland)*, *11*(16). https://doi.org/10.3390/su11164494

Barid, B., Prabawa, F., & Hairani, A. (2025). Analysis of Rural Clean Water Pipe Networks with EPANET 2.0. *Journal of Physics: International Conference on Engineering and Applied Science (ICEAT) 2024*, *2989*(1). https://doi.org/10.1088/1742-6596/2989/1/012018

Becken, S. (2014). Water equity - contrasting tourism water use with that of the local community. *Water Resources and Industry*, *7–8*, 9–22. https://doi.org/10.1016/j.wri.2014.09.002

Berkes, F., Ibarra, M. A., Armitage, D., Charles, T., Loucks, L., Makino, M., Satria, A., Seixas, C., & Abraham, J. (2014). *Community Conservation Research Network (CCRN) Guidelines for Analysis of Social-Ecological Systems Prepared by the CCRN Working Group on Social-Ecological Systems and Community Resilience*. www.CommunityConservation.Net

Berry, E. N. (2000). *An application of Butler's (1980) tourist area life cycle theory to the Cairns region, Australia, 1876-1998* [PhD Thesis, James Cook University of North Queensland]. https://doi.org/10.25903/5bebae108228c

Biondić, R., Plantak, L., Radovan, A. M., & Meaški, H. (2022). Saltwater intrusion of coastal karstic aquifer on the example of the Boljkovac water supply pumping station near Zadar, Croatia. *Quaternary*, *5*(36). https://doi.org/10.3390/quat5030036

BPS Kabupaten Gunungkidul. (2006). *Gunungkidul Regency in Figures 2006*. BPS Kabupaten Gunungkidul.

BPS Kabupaten Gunungkidul. (2023). *Gunungkidul Regency in Figures 2023*. BPS Kabupaten Gunungkidul.

Braun, V., & Clarke, V. (2013). *Successful Qualitative Research: A Practical Guide for Beginners*. SAGE Publications Ltd.

Bricheno, L. M., Wolf, J., & Sun, Y. (2021). Saline intrusion in the Ganges-Brahmaputra-Meghna megadelta. *Estuarine, Coastal and Shelf Science*, *252*. https://doi.org/10.1016/j.ecss.2021.107246

Butler, R. W. (1980). The concept of a tourist area cycle of evolution: implications for management of resources. *The Canadian Geographer*, *24*(1), 5–12. https://doi.org/10.1111/j.1541-0064.1980.tb00970.x

Butler, R. W. (2011). Tourism Area Life Cycle. In C. Cooper (Ed.), *Contemporary Tourism Reviews*. Goodfellow Publishers Limited. http://www.goodfellowpublishers.com

Butscher, C., & Huggenberger, P. (2009). Modeling the temporal variability of karst groundwater vulnerability, with implications for climate change. *Environmental Science and Technology*, *43*(6), 1665–1669. https://doi.org/10.1021/es801613g

Cahyadi, A. (2017). Peran telaga dalam pemenuhan kebutuhan air kawasan Karst Gunungsewu pasca pembangunan jaringan air bersih. *Geomedia: Majalah Ilmiah Dan Informasi Kegeografian*, *14*(2), 23–33. https://doi.org/10.21831/gm.v14i2.13813

Cahyadi, A., Haryono, E., & Barianto, D. H. (2017). *Hydrogeology of the Gunungsewu Karst Region: The 2nd PIT PAAI Fieldtrip Field Guide*. Perhimpunan Ahli Airtanah Indonesia (PAAI). https://doi.org/10.31227/osf.io/t5dgp

Campanale, C., Losacco, D., Triozzi, M., Massarelli, C., & Uricchio, V. F. (2022). An overall perspective for the study of emerging contaminants in karst aquifers. *Resources*, *11*(11). https://doi.org/10.3390/resources11110105

Carvache-Franco, O., Carvache-Franco, M., & Carvache-Franco, W. (2022). Coastal and marine topics and destinations during the COVID-19 pandemic in Twitter's tourism hashtags. *Tourism and Hospitality Research*, *22*(1), 32–41. https://doi.org/10.1177/1467358421993882

Cassivi, A., Tilley, E., Waygood, O., & Dorea, C. (2021). Seasonal preferences and alternatives for domestic water sources: A prospective cohort study in Malawi. *ACS ES&T Water*, *1*(6), 1464–1473. https://doi.org/10.1021/acsestwater.1c00045

Castilho, D., & Fuinhas, J. A. (2025). How do tourism investments affect each pillar of decent work? Evidence from European Union countries. *Safety Science*, *189*. https://doi.org/10.1016/j.ssci.2025.106896

Charles, K. J., Howard, G., Villalobos Prats, E., Gruber, J., Alam, S., Alamgir, A. S. M., Baidya, M., Flora, M. S., Haque, F., Hassan, S. M. Q., Islam, S., Lazaro, A., Lwetoijera, D. W., Mahmud, S. G., Mahmud, Z. H., Matwewe, F., Pasa, K., Rahman, M., Reza, A. A. S., … Campbell-Lendrum, D. (2022). Infrastructure alone cannot ensure resilience to weather events in drinking water supplies. *Science of the Total Environment*, *813*. https://doi.org/10.1016/j.scitotenv.2021.151876

Charlier, J.-B., Ladouche, B., & Maréchal, J.-C. (2015). Identifying the impact of climate and anthropic pressures on karst aquifers using wavelet analysis. *Journal of Hydrology*, *523*, 610–623. https://doi.org/10.1016/j.jhydrol.2015.02.003ï

Chen, L., Sela, S., Svoray, T., & Assouline, S. (2013). The role of soil-surface sealing, microtopography, and vegetation patches in rainfall-runoff processes in semiarid areas. *Water Resources Research*, *49*(9), 5585–5599. https://doi.org/10.1002/wrcr.20360

Chen, N., Hong, H., & Gao, X. (2021). Securing drinking water resources for a coastal city under global change: Scientific and institutional perspectives. *Ocean and Coastal Management*, *207*. https://doi.org/10.1016/j.ocecoaman.2018.02.023

Cheng, S., Yu, X., Li, Z., Xu, X., & Wang, K. (2024). Quantitatively distinguishing the factors driving runoff and sediment yield variations in karst watersheds. *Water Resources Research*, *60*(8). https://doi.org/10.1029/2024WR037089

Cimbaljević, M., Panić, A., Kovačić, S., Knežević, M., & Pavluković, V. (2025). What factors do tourists consider most important when evaluating the competitiveness of tourism? The focus on developing economy. *Journal of the Geographical Institute Jovan Cvijic SASA*, *75*(1), 67–85. https://doi.org/10.2298/IJGI240814015C

Cole, S., & Ferguson, L. (2015). Towards a gendered political economy of water and tourism. *Tourism Geographies*, *17*(4), 511–528. https://doi.org/10.1080/14616688.2015.1065509

Comte, J. C., Cassidy, R., Obando, J., Robins, N., Ibrahim, K., Melchioly, S., Mjemah, I., Shauri, H., Bourhane, A., Mohamed, I., Noe, C., Mwega, B., Makokha, M., Join, J. L., Banton, O., & Davies, J. (2016). Challenges in groundwater resource management in coastal aquifers of East Africa: Investigations and lessons learnt in the Comoros Islands, Kenya and Tanzania. *Journal of Hydrology: Regional Studies*, *5*, 179–199. https://doi.org/10.1016/j.ejrh.2015.12.065

D'Ascenzo, F., Martucci, O., & Rocchi, A. (2020). Sustainable tourism: Best practice in water management. *Chinese Business Review*, *19*(5). https://doi.org/10.17265/1537-1506/2020.05.002

de Stefano, L. (2004). *Freshwater and Tourism in the Mediterranean*. www.panda.org/mediterranean

De Vita, P., Allocca, V., Manna, F., & Fabbrocino, S. (2012). Coupled decadal variability of the North Atlantic Oscillation, regional rainfall and karst spring discharges in the Campania region (southern Italy). *Hydrology and Earth System Sciences*, *16*(5), 1389–1399. https://doi.org/10.5194/hess-16-1389-2012

Detik News. (2023, September 2). *344 Telaga di Gunungkidul Kering gegara Musim Kemarau*. Detik News. https://news.detik.com/berita/d-6908867/344-telaga-di-gunungkidul-kering-gegara-musim-kemarau

Dinas Lingkungan Hidup Kabupaten Gunungkidul. (2021). *Dokumen Informasi Kinerja Pengelolaan Lingkungan Hidup Daerah Tahun 2020*.

Dinas Pariwisata Kabupaten Gunungkidul. (2022). *Buku Profil Pariwisata Kabupaten Gunungkidul*. Dinas Pariwisata Kabupaten Gunungkidul.

Dinas Pariwisata Kabupaten Gunungkidul. (2024). *Rencana Kerja (Renja) Dinas Pariwisata Tahun 2024*. Dinas Pariwisata Kabupaten Gunungkidul.

Drius, M., Pugnetti, A., & Bongiorni, L. (2022). Disentangling Trade-Offs Between the State of Coastal Ecosystems with Human Well-Being and Activities as a Strategy Addressing Sustainable Tourism. In I. Misiune, D. Depellegrin, & L. E. Vigl (Eds.), *Human-Nature Interactions* (pp. 25–36). Springer International Publishing. https://doi.org/10.1007/978-3-031-01980-7_3

Dwipayanti, N. M. U., Nastiti, A., Johnson, H., Loehr, J., Kowara, M., Rozari, P. de, Vada, S., Hadwen, W., Nugraha, M. A. T., & Powell, B. (2022). Inclusive WASH and sustainable tourism in Labuan Bajo, Indonesia: needs and opportunities. *Journal of Water Sanitation and Hygiene for Development*, *12*(5), 417–431. https://doi.org/10.2166/washdev.2022.222

Eiche, E., Hochschild, M., Haryono, E., & Neumann, T. (2016). Characterization of recharge and flow behaviour of different water sources in Gunung Kidul and its impact on water quality based on hydrochemical and physico-chemical monitoring. *Applied Water Science*, *6*(3), 293–307. https://doi.org/10.1007/s13201-016-0426-z

Elgin, C., & Elveren, A. Y. (2024). Unpacking the economic impact of tourism: A multidimensional approach to sustainable development. *Journal of Cleaner Production*, *478*. https://doi.org/10.1016/j.jclepro.2024.143947

Fader, M., Giupponi, C., Burak, S., Dakhlaoui, H., Koutroulis, A., Lange, M. A., LLasat, M. C., Pulido-Velazquez, D., & Sanz-Cobeña, A. (2020). *Climate and Environmental Change in the Mediterranean Basin-Current Situation and Risks for the Future Chapter 3 Resources | Subchapter 3.1 Water*.

Fan, Y., Ji, H., Lu, R., Wan, J., & Huang, K. (2024). Control of structural landform evolution on karst groundwater cycle in a large-scale anticlinorium. *Groundwater*, *62*(2), 196–211. https://doi.org/10.1111/gwat.13341

Ford, D., & Williams, P. (2007). *Karst Hydrogeology and Geomorphology*. John Wiley & Sons, Ltd.

Fuchs, S., Silva, A., Anggraini, A. K., & Mahdariza, F. (2015). Planning and installation of a drinking water treatment in Gunungkidul, Java, Indonesia. *Water Science and Technology: Water Supply*, *15*(1), 42–49. https://doi.org/10.2166/ws.2014.080

Garcia-Castello, E., Garcia-Garrido, J., Rodriguez-Lopez, A. D., Laguarda-Miro, N., & Pascual-Garrido, J. (2007). Designing a desalination plant for a tourist city located in the Mediterranean Spanish coast. *Desalination*, *203*(1–3), 189–198. https://doi.org/10.1016/j.desal.2006.02.019

Geng, Y., Maimaituerxun, M., & Zhang, H. (2020). Coupling coordination of water governance and tourism: Measurement and prediction. *Discrete Dynamics in Nature and Society*, *2020*(1). https://doi.org/10.1155/2020/3683918

Ghosh, T. (2012). Sustainable coastal tourism: problems and management options. *Journal of Geography and Geology*, *4*(1). https://doi.org/10.5539/jgg.v4n1p163

Goldscheider, N., Chen, Z., Auler, A. S., Bakalowicz, M., Broda, S., Drew, D., Hartmann, J., Jiang, G., Moosdorf, N., Stevanovic, Z., & Veni, G. (2020). Global distribution of carbonate rocks and karst water resources. *Hydrogeology Journal*, *28*, 1661–1677. https://doi.org/10.1007/s10040-020-02139-5/Published

Gössling, S. (2015). New performance indicators for water management in tourism. *Tourism Management*, *46*, 233–244. https://doi.org/10.1016/j.tourman.2014.06.018

Gössling, S., & Hall, C. M. (2017). *Tourism and Global Environmental Change: Ecological, Social, Economic and Political Interrelationships* (S. Gössling & C. M. Hall, Eds.). Routledge.

Gössling, S., Peeters, P., Hall, C. M., Ceron, J. P., Dubois, G., Lehmann, L. V., & Scott, D. (2012). Tourism and water use: Supply, demand, and security. An international review. *Tourism Management*, *33*(1), 1–15. https://doi.org/10.1016/j.tourman.2011.03.015

Gračan, D., & Lučić, L. (2022). The impact of tourism development on the quality of life of the locals in a tourist destination. *Pomorstvo*, *36*(1), 105–112. https://doi.org/10.31217/p.36.1.12

Grecksch, K., & Landström, C. (2021). Drought and water scarcity management policy in England and Wales—Current failings and the potential of civic innovation. *Frontiers in Environmental Science*, *9*. https://doi.org/10.3389/fenvs.2021.574975

Greve, P., Kahil, T., Mochizuki, J., Schinko, T., Satoh, Y., Burek, P., Fischer, G., Tramberend, S., Burtscher, R., Langan, S., & Wada, Y. (2018). Global assessment of water challenges under uncertainty in water scarcity projections. *Nature Sustainability*, *1*(9), 486–494. https://doi.org/10.1038/s41893-018-0134-9

Griffiths, S. (2017). Renewable energy policy trends and recommendations for GCC countries. *Energy Transitions*, *1*(3), 1–15. https://doi.org/10.1007/s41825-017-0003-6

Griggs, G., Davar, L., & Reguero, B. G. (2019). Documenting a century of coastline change along central california and associated challenges: From the qualitative to the quantitative. *Water (Switzerland)*, *11*(12). https://doi.org/10.3390/W11122648

Guo, F., Yang, J., Li, H., Li, G., & Zhang, Z. (2021). A ConvLSTM Conjunction Model for groundwater level forecasting in a karst aquifer considering connectivity characteristics. *Water (Switzerland)*, *13*(19). https://doi.org/10.3390/w13192759

Guo, W., Zheng, X., Meng, F., & Zhang, X. (2019). The evolution of cultural space in a world heritage site: tourism sustainable development of Mount Wuyi, China. *Sustainability (Switzerland)*, *11*(15). https://doi.org/10.3390/su11154025

Hadjikakou, M., Chenoweth, J., & Miller, G. (2013). Water and Tourism. In A. Holden & D. Fennell (Eds.), *The Routledge Handbook of Tourism and the Environment* (1st ed., pp. 435–446). Routledge. https://doi.org/10.13140/RG.2.1.2356.5286

Haldane, E., MacDonald, L., Kressin, N., Furlotte, Z., Kınay, P., Guild, R., & Wang, X. (2023). Sustainable tourism in the face of climate change: an overview of Prince Edward Island. *Sustainability (Switzerland)*, *15*(5). https://doi.org/10.3390/su15054463

Harian Jogja. (2023, September 25). *Kekeringan di Gunungkidul Meluas, 118 Ribu Jiwa Kesulitan Air Bersih*. Harian Jogja. https://jogjapolitan.harianjogja.com/read/2023/09/25/513/1149613/kekeringan-di-gunungkidul-meluas-118-ribu-jiwa-kesulitan-air-bersih

Hariyani, H. F. (2018). Tourism sector performance on Indonesia's economic growth. *Jurnal Ekonomi Pembangunan*, *16*(1), 45–56.

Hartmann, A., Gleeson, T., Rosolem, R., Pianosi, F., Wada, Y., & Wagener, T. (2015). A large-scale simulation model to assess karstic groundwater recharge over Europe and the Mediterranean. *Geoscientific Model Development*, *8*(6), 1729–1746. https://doi.org/10.5194/gmd-8-1729-2015

Hartmann, A., Goldscheider, N., Wagener, T., Lange, J., & Weiler, M. (2014). Karst water resources in a changing world: Review of hydrological modeling approaches. *Reviews of Geophysics*, *52*(3), 218–242. https://doi.org/10.1002/2013RG000443

Hartmann, A., Liu, Y., Olarinoye, T., Berthelin, R., & Marx, V. (2020). Integrating field work and large-scale modeling to improve assessment of karst water resources. *Hydrogeology Journal*, *29*(1), 315–329. https://doi.org/10.1007/s10040-020-02258-z

Haryono, E. (2000). Some properties of epikarst drainage system in Gunung Kidul Regency, Yogyakarta, Indonesia. *The Indonesian Journal of Geography*, *32*(79–80), 75–86.

Hengky, S. H. (2023). Challenges of Sawarna coastal sustainable tourism in Banten, Indonesia. *Journal of Aquaculture & Marine Biology*, *12*(2), 138–140. https://doi.org/10.15406/jamb.2023.12.00366

Herman, J. D., Zeff, H. B., Reed, P. M., & Characklis, G. W. (2014). Beyond optimality: multistakeholder robustness tradeoffs for regional water portfolio planning under deep uncertainty. *Water Resources Research*, *50*(10), 7692–7713. https://doi.org/10.1002/2014WR015338

Hernández-Delgado, E. A. (2024). Coastal restoration challenges and strategies for small island developing states in the face of sea level rise and climate change. *Coasts*, *4*(2), 235–286. https://doi.org/10.3390/coasts4020014

Heslinga, J. H., Groote, P., & Vanclay, F. (2017). Using a social-ecological systems perspective to understand tourism and landscape interactions in coastal areas. *Journal of Tourism Futures*, *3*(1), 23–38. https://doi.org/10.1108/JTF-10-2015-0047

Hof, A., & Schmitt, T. (2011). Urban and tourist land use patterns and water consumption: Evidence from Mallorca, Balearic Islands. *Land Use Policy*, *28*(4), 792–804. https://doi.org/10.1016/j.landusepol.2011.01.007

Hornbacher, A. (2021). Bali's environmental crisis: between moral ecology and global climate discourse. *Social Anthropology*, *29*(1), 245–248. https://doi.org/10.1111/1469-8676.13006

Husain, S., Ilat, V., & Maradesa, D. (2022). Evaluasi penetapan tarif air minum pada Perusahaan Daerah Air Minum (PDAM) Kabupaten Kepulauan Sangihe. *Junrla LPPM Bidang Ekonomi, Sosial, Budaya, Dan Hukum*, *6*(1), 377–388.

Husein, S., & Srijono. (2010, March 23). Peta Geomorfologi Daerah Istimewa Yogyakarta. *Simposium Geologi Yogyakarta*.

Irshabdillah, M. R., & Widyastuti, M. (2020). Water Quality Analysis of the PDAM Drinking Water Distribution Network at the Baron-Ngobaran Management Unit, Gunungkidul Regency - Indonesia. *E3S Web of Conferences International Conference on Science and Technology*, *200*. https://doi.org/10.1051/e3sconf/202020002027

Jakada, H., Chen, Z., Luo, M., Zhou, H., Wang, Z., & Habib, M. (2019). Watershed characterization and hydrograph recession analysis: A comparative look at a karst vs. non-karst watershed and implications for groundwater resources in Gaolan River Basin, Southern China. *Water*, *11*(4). https://doi.org/10.3390/w11040743

JPNN. (2023, October 4). *Status Darurat Kekeringan di Gunungkidul Berlanjut*. JPNN. https://jogja.jpnn.com/jogja-terkini/7617/status-darurat-kekeringan-di-gunungkidul-berlanjut

Kaçaroğlu, F. (1999). Review of groundwater pollution and protection in karst areas. *Water, Air, and Soil Pollution*, *113*(1–4), 337–356. https://doi.org/10.1023/A:1005014532330

Kakoulas, D. A., Golfinopoulos, S. K., Koumparou, D., & Alexakis, D. E. (2022). The effectiveness of rainwater harvesting infrastructure in a Mediterranean Island. *Water (Switzerland)*, *14*(5). https://doi.org/10.3390/w14050716

Kementerian Keuangan. (2023, May 16). *APBN Dukung Kebangkitan Pariwisata*. Media Keuangan Kementerian Keuangan. https://mediakeuangan.kemenkeu.go.id/article/show/apbn-dukung-kebangkitan-pariwisata#:~:text=Anggaran%20Fungsi%20Pariwisata%20di%20APBN,serta%20industrialisasi%20di%20sektor%20pariwisata.

Kementerian Koordinator Bidang Kemaritiman dan Investasi. (2023). *National Action Plan on Marine Plastic Litter from Sea-based Sources*.

Kementerian PUPR. (2002). *Kebijakan Pengelolaan Sumber Daya Air*. Informasi dan Dokumentasi Hukum Direktorat Sumber Daya Air.

Kompas. (2023, September 17). *16 Kapanewon di Gunungkidul Terdampak Kekeringan tetapi Bantuan Sedikit*. Kompas. https://yogyakarta.kompas.com/read/2023/09/17/191441878/16-kapanewon-di-gunungkidul-terdampak-kekeringan-tetapi-bantuan-sedikit

Korten, J. (2023). *Freshwater Security in Small Island De-veloping States: A Case Study of Anguilla* [Thesis, Uppsala University]. www.geo.uu.se

Kusumayudha, S. B., Setiawan, J., Ciptahening, A. N., & Septianta, P. D. (2015). Geomorphologic model of Gunungsewu Karst, Gunung Kidul Regency, Yogyakarta Special Territory, Indonesia: The role of lithologic variation and geologic structure. *Journal of Geological Resource and Engineering*, *4*(1). https://doi.org/10.17265/2328-2193/2015.01.001

Langevin, C. D., & Zygnerski, M. (2013). Effect of sea-level rise on salt water intrusion near a coastal well field in Southeastern Florida. *Groundwater*, *51*(5), 781–803. https://doi.org/10.1111/j.1745-6584.2012.01008.x

Lantarsih, R., Fajri, U. N., Hariadi, U., & Perdana, P. (2023). Farmers' Interest in Land Utilization for the Development of Melon Farming with the Drip System: Case Study in Gunung Kidul Regency, Indonesia. In B. Setiawan (Ed.), *Proceedings of the 1st International Conference of Management and Business (ICoMB 2022)* (pp. 56–65). Atlantis Press. https://doi.org/10.2991/978-94-6463-160-9_7

Lehmann, L. (2008). Valuing water in dry land tourism regions. *WIT Transactions on Ecology and the Environment: Sustainable Tourism III*, *115*, 207–220. https://doi.org/10.2495/ST080211

Lemma, A. F. (2014). *Tourism Impacts Evidence of Impacts on Employment, Gender, Income*. http://partnerplatform.org/eps-peaks

Liao, H. W., Jiang, Z. C., Zhou, H., Qin, X. Q., Huang, Q. B., Zhong, L., & Pu, Z. G. (2022). Dissolved Heavy metal pollution and assessment of a karst basin around a mine,

Southwest China. *International Journal of Environmental Research and Public Health*, *19*(21). https://doi.org/10.3390/ijerph192114293

Liu, H., Jiang, Y., Zhu, H., Chen, Y., Lyu, W., Luo, W., & Yao, W. (2021). Analysis of water resource management in tourism in China using a coupling degree model. *Water Policy*, *23*(3), 765–782. https://doi.org/10.2166/wp.2021.155

Liu, J., Hrustić, E., Du, J., Gašparović, B., Čanković, M., Cukrov, N., Zhu, Z., & Zhang, R. (2019). Net submarine groundwater-derived dissolved inorganic nutrients and carbon input to the oligotrophic stratified karstic estuary of the Krka River (Adriatic Sea, Croatia). *Journal of Geophysical Research: Oceans*, *124*(6), 4334–4349. https://doi.org/10.1029/2018JC014814

Liu, W., Vogt, C. A., Lupi, F., He, G., Ouyang, Z., & Liu, J. (2016). Evolution of tourism in a flagship protected area of China. *Journal of Sustainable Tourism*, *24*(2), 203–226. https://doi.org/10.1080/09669582.2015.1071380

Liu, Y., Wagener, T., & Hartmann, A. (2021). Assessing streamflow sensitivity to precipitation variability in karst-influenced catchments with unclosed water balances. *Water Resources Research*, *57*(1). https://doi.org/10.1029/2020WR028598

Lutfia, L., Khasanah, A. U., & Hairani, A. (2024). Characteristics of Community-based Rural Water Supply System in Jambon Village, Kulon Progo City. *BIO Web of Conferences: SAGE-Grace 2024*, *144*. https://doi.org/10.1051/bioconf/202414403002

Mackay, E. A., & Spencer, A. (2017). The future of Caribbean tourism: competition and climate change implications. In *Worldwide Hospitality and Tourism Themes* (Vol. 9, Issue 1, pp. 44–59). Emerald Group Publishing Ltd. https://doi.org/10.1108/WHATT-11-2016-0069

Marazuela, M. Á., Baquedano, C., Cruz-Pérez, N., Martínez-León, J., Laspidou, C., Santamarta, J. C., & García-Gil, A. (2023). Dyke-impounded fresh groundwater resources in coastal and island volcanic aquifers: Learning from the Canary Islands (Spain). *Science of the Total Environment*, *899*. https://doi.org/10.1016/j.scitotenv.2023.165638

Marfai, M. A., Cahyadi, A., & Anggraini, D. F. (2013). Tipologi, dinamika, dan potensi bencana di pesisir kawasan karst Kabupaten Gunungkidul. *Forum Geografi*, *27*(2), 147–158.

Marx, S. (2023). Mapping as critical qualitative research methodology. *International Journal of Research and Method in Education*, *46*(3), 285–299. https://doi.org/10.1080/1743727X.2022.2110231

Mastrocicco, M., & Colombani, N. (2021). The issue of groundwater salinization in coastal areas of the Mediterranean region: A review. *Water (Switzerland)*, *13*(1). https://doi.org/10.3390/w13010090

Mawardi, I. (2008). Upaya meningkatkan daya dukung sumberdaya air Pulau Jawa. *Jurnal Teknik Lingkungan*, *9*(1), 98–107.

Miller, S. J. (2015). *Evaluating the Effectiveness of Costa Rica's Sustainable Tourism Policy* [Thesis]. The State University of New Jersey.

Mohammad, A. H., Odeh, T., Abualhaijaa, M., Shatanawi, K., & Halalshe, M. (2024). Application of the fuzzy analytic hierarchy process for water resources in the Wadi AlHasa catchment, Jordan. *Journal of Water and Land Development*, *60*, 100–111. https://doi.org/10.24425/jwld.2024.149112

Morote, A.-F., Saurí, D., & Hern, M. (2016). Residential tourism, swimming pools, and water demand in the Western Mediterranean. *The Professional Geographer*, *69*(1), 1–11.

Murgulet, D., Cook, M., & Murgulet, V. (2016). Groundwater mixing between different aquifer types in a complex structural setting discerned by elemental and stable isotope geochemistry. *Hydrological Processes*, *30*(3), 410–423. https://doi.org/10.1002/hyp.10589

Murshed, S. B., & Kaluarachchi, J. J. (2018). Scarcity of fresh water resources in the Ganges Delta of Bangladesh. *Water Security*, *4–5*, 8–18. https://doi.org/10.1016/j.wasec.2018.11.002

Musmulyadi, & Setyowati, Y. (2022). Governabilitas peran Pemerintah Desa Girikarto dalam pengembangan wisata Heha Ocean View. *Jurnal Administrasi Pemerintahan Desa*, *3*(2), 117–134. https://doi.org/10.32669

Mustika, A., Rahmatiyah, V., Mukti, M. L., Khofifah, I. M., Alhi, F. Z., & Purnomo, N. H. (2024). Potential vulnerability to hydrological disasters in the Gunungsewu Gunungkidul karst area. *Proceedings of the 4th International Conference on Social Sciences and Law (ICSSL 2024)*, 348–365. https://doi.org/10.2991/978-2-38476-303-0_34

Naeem, M., Ozuem, W., Howell, K., & Ranfagni, S. (2023). A step-by-step process of thematic analysis to develop a conceptual model in qualitative research. *International Journal of Qualitative Methods*, *22*, 1–18. https://doi.org/10.1177/16094069231205789

Neilson, B. T., Tennant, H., Stout, T. L., Miller, M. P., Gabor, R. S., Jameel, Y., Millington, M., Gelderloos, A., Bowen, G. J., & Brooks, P. D. (2018). Stream centric methods for determining groundwater contributions in karst mountain watersheds. *Water Resources Research*, *54*(9), 6708–6724. https://doi.org/10.1029/2018WR022664

Nicholls, M. (2014). *Implications for Tourism Key Findings from the Intergovernmental Panel on Climate Change Fifth Assessment Report*. www.ipcc.ch

Nugroho, J., Zid, M., & Miarsyah, M. (2020). Potensi sumber air dan kearifan masyarakat dalam menghadapi risiko kekeringan di wilayah karst (Kabupaten Gunung Kidul, Provinsi Yogyakarta). *Jurnal Pengelolaan Lingkungan Berkelanjutan*, *4*(1), 438–447. http://www.bkpsl.org/ojswp/index.php/jplbJPLB,4

Nuraini, F. (2012). *Kajian Karakteristik dan Potensi Kawasan Karst untuk Pengembangan Ekowisata di Kecamatan Ponjong, Kabupaten Gunungkidul* [Undergraduate Thesis]. Universitas Negeri Yogyakarta.

Nurmalia, U. (2019). *Identifikasi Permasalahan Sistem Penyediaan Air Minum di Kabupaten Gunungkidul, Daerah Istimewa Yogyakarta* [Undergraduate Thesis]. Universitas Islam Indonesia.

Omar, S. I., Othman, A. G., Mohamed, B., & Bahauddin, A. (2015). Coastal resort life cycle: An overview of Tioman Island, Malaysia. *Tourism Planning and Development*, *12*(3), 266–280. https://doi.org/10.1080/21568316.2014.947438

Orams, M., & Lück, M. (2013). The Routledge Handbook of Tourism and the Environment. In A. Holden & D. Fennell (Eds.), *The Routledge Handbook of Tourism and the Environment*. Routledge.

Padrón-Fumero, N., Bauluz, A., Díaz-Hernández, J. J., Diaz-Farina, E., & Hernández-Yumar, A. (2025). Unlocking water saving potential in tourism destinations using Smart Water Meters. *Current Issues in Tourism*. https://doi.org/10.1080/13683500.2025.2519662

Page, S. J., Essex, S., & Causevic, S. (2014). Tourist attitudes towards water use in the developing world: A comparative analysis. *Tourism Management Perspectives*, *10*, 57–67. https://doi.org/10.1016/j.tmp.2014.01.004

Pandy, W. R., & Rogerson, C. M. (2021). Coastal tourism and climate change: Risk perceptions of tourism stakeholders in South Africa's garden route. *Geojournal of Tourism and Geosites* , *37*(3), 730–739. https://doi.org/10.30892/GTG.37301-703

Parlindungan, H. H., & Manurung, H. (2023). Indonesia effort to attracting investment in tourist destination development. *Jurnal Industri Pariwisata*, *5*(2), 177–188.

Parwita, I. G. L. M., Dharma, I. G. B. S., Yekti, M. I., Suryantara P, I. P. G., & Santosa, I. G. N. (2023). Operational analysis of South Bali's integrated regional water company related to the Sidan Dam operational plan. *International Research Journal of Engineering, IT & Scientific Research*, *9*(4), 133–147. https://doi.org/10.21744/irjeis.v9n4.2345

Paszkowski, A., Goodbred, S., Borgomeo, E., Khan, M. S. A., & Hall, J. W. (2021). Geomorphic change in the Ganges–Brahmaputra–Meghna delta. *Nature Reviews Earth and Environment*, *2*(11), 763–780. https://doi.org/10.1038/s43017-021-00213-4

Pavón, D., Gabarda-Mallorquí, A., & Ribas, A. (2018). What governance? The role of public and private stakeholders in water supply management in Mediterranean coastal tourist destinations: The case of the Costa Brava. *Water (Switzerland)*, *10*(12). https://doi.org/10.3390/w10121758

Pemerintah Kabupaten Gunungkidul. (2007). *Laporan Status Lingkungan Hidup Daerah Kabupaten Gunung Kidul Tahun 2007 Pemerintah Kabupaten Gunung Kidul*.

Peng, G., Gao, X., Naseem, A., Zhang, Y., Wang, X., Fu, W., Yu, F., Ma, S., Shi, W., Yi, L., Li, C., Liu, W., & Kong, S. (2025). Karst water quality, source of pollution, and health risk assessment in China. *Science of the Total Environment*, *973*. https://doi.org/10.1016/j.scitotenv.2025.179120

Petrosillo, I., Aretano, R., & Zurlini, G. (2015). Socioecological Systems. In B. Fath (Ed.), *Reference Module in Earth Systems and Environmental Sciences: Encyclopedia of*

Ecology (Second Edition) (2nd ed., Vol. 4, pp. 419–425). Elsevier. https://doi.org/10.1016/B978-0-12-409548-9.09518-X

Phan, T. D., Smart, J. C., Capon, S. J., Hadwen, W. L., & Sahin, O. (2015). An Imbalance Assessment of Coastal Water Supply and Demand in a Highly Populated Area: A System Dynamics Approach. *21st International Congress on Modelling and Simulation*, 2402–2408. www.mssanz.org.au/modsim2015

Pihljak, L. H., Rusca, M., Alda-Vidal, C., & Schwartz, K. (2021). Everyday practices in the production of uneven water pricing regimes in Lilongwe, Malawi. *Environment and Planning C: Politics and Space*, *39*(2), 300–317. https://doi.org/10.1177/2399654419856021

Pjanić, M. (2019). Economic effects of tourism on the world economy. In V. Bevanda & S. Štetić (Eds.), *4th International Thematic Monograph Modern Management Tools and Economy of Tourism Sector in Present Era* (Vol. 5, pp. 291–305). Association of Economists and Managers of the Balkans; Faculty of Tourism and Hospitality, Ohrid, North Macedonia. https://doi.org/https://doi.org/10.31410/tmt.2019.291

Pradipta, I. G. N. G. A., & Putri, L. G. S. (2024). Sustainable water governance based on the local wisdom of Tri Hita Karana and Sad Kertih values: Impact for environmental sustainability. *International Journal of Environmental Impacts*, *7*(2), 181–190. https://doi.org/10.18280/ijei.070203

Praja, T. T., Wardani, D. W. S. R., Iryani, D. A., Wahono, E. P., Setiajaya, A., & Zulaicha, A. S. (2024). Evaluation of community participation in community-based drinking water and sanitation program. *Jurnal Kesehatan Lingkungan: Jurnal Dan Aplikasi Teknik Kesehatan Lingkungan*, *21*(1), 71–80. https://doi.org/10.31964/jkl.v21i1.721

Purnomo, A., Rahmanu, Y. A., Kintani, P. C., & Pertamaningtias, A. H. (2016, November). Typology Coastal Mapping to Promote Sustainable Coastal Development and Marine Resources Management (Case Study: Southern Coastal of Yogyakarta). *The 2ndASEAN Geography Student Conference (AGSC)*.

PwC Indonesia. (2023). *PwC Indonesia Economic Update - Second Quarter 2023*.

Qin, L., Bai, X., Wang, S., Zhou, D., Li, Y., Peng, T., Tian, Y., & Luo, G. (2015). Major problems and solutions on surface water resource utilisation in karst mountainous areas. *Agricultural Water Management*, *159*, 55–65. https://doi.org/10.1016/j.agwat.2015.05.024

Qiuyun, J., Guoji, F., Mulian, L., Yujun, W., & Jingxuan, X. (2011). Research on tourism water resources carrying capacity engineering in Hainan Province. *Systems Engineering Procedia*, *1*, 384–391. https://doi.org/10.1016/j.sepro.2011.08.058

Rahman, M. A., & Islam, M. N. (2018). Scarcity of safe drinking water in the south-west coastal Bangladesh. *J. Environ. Sci. & Natural Resources*, *11*(2), 17–25.

Rajaveni, S. P., Nair, I. S., & Elango, L. (2016). Evaluation of impact of climate change on seawater intrusion in a coastal aquifer by finite element modelling. *Journal of Climate Change*, *2*(2), 111–118. https://doi.org/10.3233/jcc-160022

Ranjbar, A., Cherubini, C., & Saber, A. (2020). Investigation of transient sea level rise impacts on water quality of unconfined shallow coastal aquifers. *International Journal of Environmental Science and Technology*, *17*(5), 2607–2622. https://doi.org/10.1007/s13762-020-02684-2

Refaat, S. A. (2015). Egyptian Tourism with the Expected Water Scarcity Crisis. In V. Katsoni (Ed.), *Springer Proceedings in Business and Economics: Cultural Tourism in a Digital Era* (pp. 39–56). Springer. http://www.springer.com/series/11960

Regent of Gunungkidul Regulation Number 45 of 2011 on Wastewater Treatment (2011).

Regional Law of Gunungkidul Regency Number 8 of 2020 on Amendment of Regional Law of Gunungkidul Regency Number 3 of 2014 on Masterplan of Gunungkidul Regency Regional Tourism Development of 2014 – 2025 (2020).

Regional Law of Gunungkidul Regency Number 9 of 2019 on Tirta Handayani Regional Drinking Water Company (2019).

Reyers, B., Folke, C., Moore, M.-L., Biggs, R., & Galaz, V. (2018). *Annual review of environment and resources Social-Ecological Systems insights for navigating the dynamics of the anthropocene*. *43*, 267–289. https://doi.org/10.1146/annurev-environ

Ricart, S., Villar-Navascués, R., Reyes, M., Rico-Amorós, A. M., Hernández-Hernández, M., Toth, E., Bragalli, C., Neri, M., & Amelung, B. (2024). Water–tourism nexus research in the Mediterranean in the past two decades: a systematic literature review. *International Journal of Water Resources Development*, *40*(1), 57–83. https://doi.org/10.1080/07900627.2023.2207686

Rico-Amoros, A. M., Olcina-Cantos, J., & Sauri, D. (2009). Tourist land use patterns and water demand: Evidence from the Western Mediterranean. *Land Use Policy*, *26*(2), 493–501. https://doi.org/10.1016/j.landusepol.2008.07.002

Rose, M. D. (2022). Sinkhole flooding and aquifer recharge in arid to dry sub-humid regions: A systematic review in the perspective of climate change. *Hydrology*, *9*(2). https://doi.org/10.3390/hydrology9020025

Rucks-Ahidiana, Z., & Bierbaum, A. H. (2015). Qualitative spaces: Integrating spatial analysis for a mixed methods approach. *International Journal of Qualitative Methods*, *14*, 92–103.

Rutty, M., & Scott, D. (2016). Comparison of climate preferences for domestic and international beach holidays: A case study of Canadian travelers. *Atmosphere*, *7*(2). https://doi.org/10.3390/atmos7020030

Sahrina, A., Fitrianti, D., Suprianto, A., & Labib, M. A. (2020). Potential and Challenges of Karst Water Resources in Sumbermanjing Wetan District of Malang Regency. *IOP Conference Series: Earth and Environmental Science: 2nd International Conference on Geography and Education*, *412*(1). https://doi.org/10.1088/1755-1315/412/1/012032

Said, N. I., Mahasti, N. N. N., Widayat, W., Hernaningsih, T., Yudo, S., Chandrawaty, D., Fani, A. M., Shoiful, A., Fuad, N. M., Luvita, V., Nugroho, R., Primeia, S., Ikbal, Arifudin, Nugraha, Y. W., Setiyono, & Septian, A. (2025). Application of large-scale

honeycomb biofilter as pretreatment system to improve the quality of raw city water: Efficiency and economic analysis. *Journal of Water Process Engineering*, *71*. https://doi.org/10.1016/j.jwpe.2025.107213

Santos, J. R. dos, Franco, E. F., Carvalho, H. C., Armenia, S., Pompei, A., & Medaglia, C. M. (2019). Water used to be infinite: a Brazilian tale of climate change. *Kybernetes*, *48*(1), 143–162. https://doi.org/10.1108/K-11-2017-0438

Sappa, G., Vitale, S., & Ferranti, F. (2018). Identifying karst aquifer recharge areas using environmental isotopes: A case study in central Italy. *Geosciences (Switzerland)*, *8*(9). https://doi.org/10.3390/geosciences8090351

Saraswaty, A. N. (2024). Revealing the economic challenges on adaptive sacred water management in Balinese community. *Journal of Social Development Studies*, *5*(1), 43–53. https://doi.org/10.22146/jsds.10548

Sari, R. K. (2009). *Kinerja Perusahaan Daerah Air Minum (PDAM) Kabupaten Gunungkidul dalam Kegiatan Penyediaan Air Bersih* [Undergraduate Thesis]. Universitas Sebelas Maret.

Sari, W. P., Pandrianto, N., Azeharie, S., Sukendro, G. G., & Irena, L. (2024). The existence of tourism and local culture: A study of the TALC tourism model in Bali. *Revista de Gestão Social e Ambiental*, *18*(11), 1–18. https://doi.org/10.24857/rgsa.v18n11-051

Sarminingsih, A., Rezagama, A., Wahyudi, R. S., & Munawafa, S. N. N. (2021). Underground River Resources Potential in Gunungkidul Regency for Drinking Water. *IOP Conference Series: Earth and Environmental Science, International Conference on Environment, Sustainability Issues, and Community Development (INCRID)*, *623*(1). https://doi.org/10.1088/1755-1315/623/1/012066

Schorr, J., Jud, F., la Cecilia, D., Beck, B., Longree, P., Singer, H., & Hollender, J. (2024). Tracing pesticide dynamics: High resolution offers new insights to karst groundwater quality. *Water Research*, *267*. https://doi.org/10.1016/j.watres.2024.122412

Sears, A. E. (2015). *Hydrologic Response and Erosion Modeling of Geomorphic Landform Reclamation in Mountainous Terrain Landform Reclamation in Mountainous Terrain* [Graduate Theses, Dissertations, and Problem Reports, West Virginia University]. https://researchrepository.wvu.edu/etd

Setiawan, A. R., Gravitiani, E., & Rahardjo, M. (2021). Production cost efficiency analysis of regional water companies in eastern Indonesia. *IOP Conference Series: Earth and Environmental Science*, *724*(1). https://doi.org/10.1088/1755-1315/724/1/012012

Setiawan, B. W. (1999). *Hotel di Kawasan Wisata Pantai Krakal Kabupaten Dati II Gunungkidul Daerah Istimewa Yogyakarta: Mengekspresikan Legenda Ratu Pantai Selatan ke dalam Bentuk Arsitektur Hotel* [Theses]. Universitas Islam Indonesia.

Shah, I. A. (2023). Exploring governance effectiveness, tourism development and poverty reduction relationship in SAARC countries using panel dynamic estimation. *Journal of Tourism Futures*. https://doi.org/10.1108/JTF-09-2022-0221

Shepard, F. (1937). Revised classification of marine shorelines. *Journal of Geology*, *45*, 602–624.

Sidauruk, P., Satrio, S., Pujiindiyati, E. R., & Aliyanta, B. (2017). Upstream hydraulic interconnection study of Gunungkidul karst area underground rivers. *Eksplorium*, *38*(2), 81–88. https://doi.org/10.17146/eksplorium.2017.38.2.3715

Siddiquee, M. S. H., & Ahamed, R. (2020). Exploring water consumption in Dhaka City using instrumental variables regression approaches. *Environmental Processes*, *7*(4), 1255–1275. https://doi.org/10.1007/s40710-020-00462-3

Sinha, A., Driha, O., & Balsalobre-Lorente, D. (2020). Tourism and inequality in per capita water availability: is the linkage sustainable? *Environmental Science and Pollution Research*, *27*(9), 10129–10134. https://doi.org/10.1007/s11356-020-07955-6

Smith, T. F., Elrick-Barr, C. E., Thomsen, D. C., Celliers, L., & Le Tissier, M. (2023). Impacts of tourism on coastal areas. *Cambridge Prisms: Coastal Futures*, *1*(5), 1–5. https://doi.org/10.1017/cft.2022.5

Song, K., Yang, G., Wang, F., Liu, J., & Liu, D. (2020). Application of geophysical and hydrogeochemical methods to the protection of drinking groundwater in karst regions. *International Journal of Environmental Research and Public Health*, *17*(10). https://doi.org/10.3390/ijerph17103627

Soviana, N. N., Putra, D. P. E., & Marliyani, G. I. (2023). Springs and Tourism Facilities Development in Purwosari, Gunungkidul, Special Region of Yogyakarta, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *1233*(1). https://doi.org/10.1088/1755-1315/1233/1/012019

Steele, P., Halimanjaya, A., & Pasaribu, K. (2021). *Investing in Sustainable Natural Capital in ASEAN Enhanced Regional EU-ASEAN Dialogue Instrument (E-READI)*.

Stevanović, Z., Gunn, J., Goldscheider, N., & Ravbar, N. (2024). *Karst: Environment and Management of Aquifers* (E. Poeter & J. Cherry, Eds.). The Groundwater Project.

Strauß, S. (2011). Water conflicts among different user groups in South Bali, Indonesia. *Human Ecology*, *39*(1), 69–79. https://doi.org/10.1007/s10745-011-9381-3

Sudipa, N., Mahendra, M. S., Adnyana, W. S., & Pujaastawa, I. B. (2020). Daya dukung air di kawasan pariwisata Nusa Penida, Bali. *Jurnal Sumberdaya Alam Dan Lingkungan*, *7*(3), 117–123. https://doi.org/10.21776/ub.jsal.2020.007.03.4

Sun, Y. Y., & Hsu, C. M. (2019). The decomposition analysis of tourism water footprint in Taiwan: Revealing decision-relevant information. *Journal of Travel Research*, *58*(4), 695–708. https://doi.org/10.1177/0047287518757371

Sustainable Hospitality Alliance. (2013). *Water Risk Assessment*. www.siwi.org

Švara, A., Mihevc, A., & Zupan Hajna, N. (2022). Active and relict contact karst morphological forms of the Slavina Corrosional Plain. *Acta Carsologica*, *51*(2), 21–41. https://doi.org/10.3986/ac.v51i2.10788

Swarbooke, J. (2023). *Why Sustainable Tourism Failed*. Responsible Tourim Partnership. https://responsibletourismpartnership.org/rtp-library/

Tabash, M. I. (2017). The role of tourism sector in economic growth: An empirical evidence from Palestine. *International Journal of Economics and Financial Issues*, *7*(2), 103–108. http:www.econjournals.com

Tarigan, H., Dharmawan, A. H., Tjondronegoro, S., & Suradisastra, K. (2013). Persaingan akses sumber daya air di Yeh Ho, Tabanan, Bali. *Jurnal Agro Ekonomi*, *31*(2), 143–159.

Tedeschi, S. (1986). Use of water in Adriatic Coastal tourist sites. *Water, Science, and Technology*, *18*(9), 175–183. http://iwaponline.com/wst/article-pdf/18/9/175/97964/175.pdf

Tian, M., Min, Q., Lun, F., Yuan, Z., Fuller, A. M., Yang, L., Zhang, Y., & Zhou, J. (2015). Evaluation of tourism water capacity in agricultural heritage sites. *Sustainability (Switzerland)*, *7*(11), 15548–15569. https://doi.org/10.3390/su71115548

Tomaz, P. A., Santos, J. de O., & Jepson, W. (2023). Household water insecurity and social vulnerability in the municipal context of the semi-arid region of Ceará. *Sociedade & Natureza*, *35*, 1–12. https://doi.org/10.14393/sn-v35-2023-69988x

Tooman, L. A. (1997). Applications of the life-cycle model in tourism. *Annals of Tourism Research*, *24*(1), 214–234.

Triyanti, R., & Susilowati, I. (2018). Characteristics and Economic Value of Tourism Services in Coastal Area of Gunungkidul Regency. *ICENIS 2018 E3S Web of Conferences*. https://doi.org/10.1051/e3sconf/201873

Turp, M. T., An, N., Bilgin, B., Şimşir, G., Orgen, B., & Kurnaz, M. L. (2024). Projected summer tourism potential of the Black Sea Region. *Sustainability (Switzerland)*, *16*(1). https://doi.org/10.3390/su16010377

USACE. (1995). Coastal Classification and Morphology. In *Engineering and Design Manual Coastal Geology EM 1110-2-1810*. Department of the Army U.S. Army Corps of Engineers.

Valente, A., Catani, V., Esposito, L., Leone, G., Pagnozzi, M., & Fiorillo, F. (2022). Groundwater resources in a complex karst environment involved by wind power farm construction. *Sustainability*, *14*(19). https://doi.org/10.3390/su141911975

Vila, M., Afsordegan, A., Agell, N., Sánchez, M., & Costa, G. (2018). Influential factors in water planning for sustainable tourism destinations. *Journal of Sustainable Tourism*, *26*(7), 1241–1256. https://doi.org/10.1080/09669582.2018.1433183

Villar, R., & Arahuetes, A. (2017). Mapping urban water governance models in the Spanish mediterranean coastline. *WIT Transactions on Ecology and the Environment*, *216*, 75–85. https://doi.org/10.2495/WS170071

Wang, Y., Shuai, C., Chen, X., Huang, W., Sun, J., & Zhao, B. (2025). Estimating water scarcity risks under climate change: A provincial perspective in China. *Water Environment Research*, *97*(3). https://doi.org/10.1002/wer.70031

Wang, Y., & Tziamalis, A. (2023). International tourism and income inequality: The role of economic and financial development. *Tourism Economics*, *29*(7), 1836–1864. https://doi.org/10.1177/13548166231177106

Warnken, J., Thompson, D., & Zakus, D. H. (2001). Golf course development in a major tourist destination: Implications for planning and management. *Environmental Management*, *27*(5), 681–696. https://doi.org/10.1007/s002670010179

Welsh, K., & Bowleg, J. (2022). Interventions and solutions for water supply on small islands: The case of New Providence, The Bahamas. *Frontiers in Water*, *4*.

Widura, E., & Mardiatno, D. (2022). Assessment of the Coastal Vulnerability Index (CVI) for disaster mitigation strategies in some coastal tourism areas in Gunungkidul, Yogyakarta-Indonesia. *IOP Conference Series: Earth and Environmental Science*, *989*(1). https://doi.org/10.1088/1755-1315/989/1/012014

Widyastuti, M., & Haryono, E. (2016). Water quality characteristics of Jonge Telaga (Doline Pond) as water resources for the people of Semanu District Gunungkidul Regency. *Indonesian Journal of Geography*, *48*, 157–167.

Winter, T. C., Harvey, J. W., Franke, O. L., & Alley, W. M. (1998). *Ground Water and Surface Water : A Single Resource*. US Geological Survey.

Witzel, A., & Reiter, H. (2013). The Problem-Centred Interview: Principles and Practice. In *The Problem-Centred Interview: Principles and Practice*. SAGE Publications Ltd. https://doi.org/10.4135/9781446288030

Yamamoto, E. M. S., Sayama, T., & Takara, K. (2021). Impact of rapid tourism growth on water scarcity in Bali, Indonesia. *Indonesian Journal of Limnology*, *2*(1), 1–16. https://doi.org/10.51264/inajl.v2i1.14

Yang, Z., Li, B., Wu, H., Li, M. H., Fan, J., Chen, M., & Long, J. (2023). Water consumption prediction and influencing factor analysis based on PCA-BP neural network in karst regions: a case study of Guizhou Province. *Environmental Science and Pollution Research*, *30*(12), 33504–33515. https://doi.org/10.1007/s11356-022-24604-2

Ye, X. (2023). Impacts of climate change on tourism in coastal areas. *Advances in Economics, Management and Political Sciences*, *62*(1), 271–276. https://doi.org/10.54254/2754-1169/62/20231359

Yogafanny, E., & Legono, D. (2021). Assessment of Groundwater Vulnerability using COP Method to Support the Groundwater Protection in Karst Area. *IOP Conference Series: Earth and Environmental Science*, *930*(1). https://doi.org/10.1088/1755-1315/930/1/012036

Yu, X., Yang, J., Graf, T., Koneshloo, M., O'Neal, M. A., & Michael, H. A. (2016). Impact of topography on groundwater salinization due to ocean surge inundation. *Water Resources Research*, *52*(8), 5794–5812. https://doi.org/10.1002/2016WR018814

Yuliatmi, A. T. (2014). *Potensi dan Upaya Pengembangan Obyek Wisata Pantai Sepanjang Desa Kemadang Kecamatan Tanjungsari Kabupaten Gunungkidul* [Theses]. Universitas Negeri Yogyakarta.

Zaimes, G. N., Iakovoglou, V., Syropoulos, D., Kaltsas, D., & Avtzis, D. (2021). Assessment of two adjacent mountainous riparian areas along Nestos River tributaries of Greece. *Forests*, *12*(9). https://doi.org/10.3390/f12091284

Zetland, D. (2021). The role of prices in managing water scarcity. *Water Security*, *12*. https://doi.org/10.1016/j.wasec.2020.100081

Zhang, W., Xin, C., & Yu, S. (2023). A review of heavy metal migration and its influencing factors in karst groundwater, Northern and Southern China. *Water*, *15*(20). https://doi.org/10.3390/w15203690

Zhao, H. (2018). A review on the adaptability of tourism and social-ecosystem. *Journal of Service Science and Management*, *11*(6), 565–577. https://doi.org/10.4236/jssm.2018.116038

Zhong, S., Hou, B., Zhang, J., Wang, Y., Xu, X., Li, B., & Ni, J. (2023). Ecological differentiation and assembly processes of abundant and rare bacterial subcommunities in karst groundwater. *Frontiers in Microbiology*, *14*. https://doi.org/10.3389/fmicb.2023.1111383

Zhu, H., Zhou, J., Liu, Z., Yang, L., & Liu, Y. (2021). Hydrogeochemistry evidence for impacts of chemical acidic wastewater on karst aquifer in Dawu water source area, Northern China. *International Journal of Environmental Research and Public Health*, *18*(16). https://doi.org/10.3390/ijerph18168478

Żywiec, J., Szpak, D., Wartalska, K., & Grzegorzek, M. (2024). The impact of climate change on the failure of water supply infrastructure: a bibliometric analysis of the current state of knowledge. *Water (Switzerland)*, *16*(7). https://doi.org/10.3390/w16071043

APPENDICES

Appendix I: Ethical Clearance Approval from the Corresponding Officials

KOMISI ETIK BIDANG SOSIAL HUMANIORA
BADAN RISET DAN INOVASI NASIONAL

ETHICAL COMMITTEE ON SOCIAL STUDIES AND HUMANITIES- NATIONAL RESEARCH AND INNOVATION AGENCY
Gedung B.J. Habibie Lantai 8 Jalan M.H. Thamrin No. 8, Jakarta 10340 Indonesia
Website: https://klirensetik.brin.go.id/, Email: klirensetik@brin.go.id

PERSETUJUAN KLIRENS ETIK RISET SOSIAL HUMANIORA
ETHICAL CLEARANCE APPROVAL ON SOCIAL STUDIES AND HUMANITIES RESEARCH

No: 642/KE.01/SK/07/2024

Komisi Etik Bidang Sosial Humaniora BRIN menerangkan bahwa,
Herewith The Ethics Committee on Social Studies and Humanities National Research and Innovation Agency (NRIA) informs that,

Judul Penelitian *Research Title*	:	Water Services in the Coastal Tourism Zone of Gunungkidul Karst
Nomor Usulan *Application Number*	:	26062024000022
Unit/Lembaga *Unit/Institution*	:	School of Geography and the Environment, University of Oxford
Koordinator Periset *Research Coordinator*	:	Aji Wijaya Abadi

Telah disidangkan pada tanggal 17 Juli 2024.
Has been evaluated in the meeting on Juli 17th, 2024.

Berdasarkan hasil sidang tersebut, Komisi Etik Bidang Sosial Humaniora BRIN memutuskan: **Riset dengan Nomor Usulan di atas telah memenuhi persyaratan Klirens Etik dengan jangka waktu riset dari bulan Juli 2024 s.d Desember 2024.**
Based on the results of the meeting, the Ethics Committee on Social Studies and Humanities NRIA has made the decision: ***The research with the application number has met the ethical clearance requirements with a period of research from July 2024 to December 2024.***

Periset tetap berkewajiban untuk:
Researchers remain obligated to:

a. Mengajukan permohonan baru apabila ada amandemen rancangan atau subyek riset;
   Submit a new application shall there be amendment to research design or research subject;
b. Memberikan laporan apabila riset Lapangan telah selesai; dan
   Submit a report when the field research has been completed; and
c. Memberikan informasi bila ada perubahan lokasi, waktu riset dan/atau dihentikan sebelum waktunya.
   Provide information if there is a change in location, research time and/or termination ahead of schedule.

Komisi Etik Bidang Sosial Humaniora BRIN mempunyai hak untuk melakukan pemantauan selama riset berlangsung.
The Ethical Committee on Social Studies and Humanities NRIA has the right to conduct monitoring during the research.

Jakarta, *19th of July 2024*
Ketua Komisi Etik Bidang Sosial Humanira BRIN,
Chief of Ethical Committee on Social Studies and Humanities NRIA

TT ELEKTRONIK

Dr. Augustina Situmorang, M.A.

Dokumen ini ditandatangani secara elektronik menggunakan sertifikat dari BSrE, silahkan lakukan verifikasi pada dokumen elektronik yang dapat diunduh dengan melakukan scan QR Code

Appendix II: Participant Information Sheet

School of Geography and the Environment
Oxford University Centre for the Environment
University of Oxford
South Parks Road
Oxford, OX1 3QY
United Kingdom
enquiries@geog.ox.ac.uk
Telephone: +44 (0)1865 285070

[Dr Kevin Grecksch (PI)]
[kevin.grecksch@ouce.ox.ac.uk]
[Aji Wijaya Abadi (MPhil in Water Science, Policy and Management)]
Oxford University email address: aji.abadi@oriel.ox.ac.uk

[Water Services in the Coastal Tourism Zone of Gunungkidul Karst]

PARTICIPANT INFORMATION SHEET

Central University Research Ethics Committee Approval Reference: [SOGE C1A 24 74]

1. **Introductory paragraph**

You are being invited to take part in a research project. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether you wish to take part.

2. **Why is this research being conducted?**

The aim of this research is to investigate the water service systems and their challenges in coastal tourism and explore how they vary across the Gunungkidul coasts. This research will focus on the dynamics of water issues in an expanding coastal tourism activity environment along the Gunungkidul coastal area from the social-ecological point of view. The result of the research will academically construct a firmer understanding of the interdisciplinary water issues within the water-tourism nexus, particularly in a water-scarcity-prone region like Gunungkidul. The findings can also be a guide for the local governing institutions that work on coastal planning in addressing problems that threaten the sustainability of water services in coastal areas. Also, the policymakers can employ the findings in the decision-making process to better understand the complexity and address the issues appropriately, concerning their plan for developing tourist attractions in the coastal area.

3. **Why have I been invited to take part?**

Based on the criteria I am using for this study, you're a good fit to take part. I'm looking into people who are involved in water services and coastal tourism, like yourself. Unlike tourists who just visit beaches for a short time and aren't really connected to the everyday water stuff, you're more in tune with what's going on around you. That means your input could give us a better understanding of things compared to what we'd get from regular tourists.

4. **Do I have to take part?**

No. It is up to you to decide whether to take part. You can withdraw yourself from the research, without giving a reason, and without negative consequences, by advising me of this decision.

5. What will happen to me if I take part in the research?

If you agree to participate in this research:

- We kindly request your oral consent indicating your willingness to participate in the interview.
- Prior to the interview, you'll receive a brief overview of my research and the topics we'll discuss.
- Your active participation during the interview is greatly appreciated, and we ask for your clear and honest responses to the questions asked.
- With your permission, I would like to record the interview audio and take photographs of any relevant materials you share. This ensures accuracy in transcribing and analysing the data for my research.
- Your interview will only occur once, and your responses will be securely stored once it concludes.
- Feel free to request a pause or stop the interview at any point if necessary.
- Following the interview, you're welcome to leave at your convenience as no further follow-up is required.

6. What are the possible disadvantages and risks in taking part?

Participants in this research are not expected to encounter any disadvantages or risks by participating.

7. Are there any benefits in taking part?

While there are no immediate benefits for those people participating in the research, it is hoped that this research will lead to better water services and coastal tourism management in the future.

8. What information will be collected and why is the collection of this information relevant for achieving the research objectives?

The researcher [*and/ or research team, supervisor, collaborator/ translator/ transcriber/ other authorised personnel*] will have access to the research data. The data that will be collected includes:

1. Subsector/activities in the coastal tourism area (water use or water demand)
2. Variance of water availability and water quality (water source)
3. Water supply methods and infrastructures (how water is supplied, collected, or distributed for the activities)
4. Presence of environmental impact or degradation affecting the water services
5. Water accessibility, affordability, and equity
6. Adopted local policy or technology (treatment, distribution, conservation)
7. Climate change (frequency of water crises/scarcity/droughts)
8. Involvement of local communities in water management (planning, implementation, evaluation)
9. WaSH aspects (waterborne diseases requiring attention)

The abovementioned question topics are relevant for achieving the research objectives because those data are required to analyse how water services operate regularly in the coastal tourism area and to investigate the existing challenges that need to be addressed.

All data (including Oral Consent Forms) will be stored [*in my One Drive for at least three years after the research is completed*]. Research data will be stored for [**5**] years after publication or public release

of the work of research. Regarding pseudonymisation, I will maintain a separate document securely storing the mapping between codes and the real names of the participants or interviewees to ensure data accuracy. Any data transfer will be done securely and with a similar level of data protection as required under UK law. I would like to use the research data in future studies and to share this with other researchers (e.g. in online databases). I'm dedicated to keeping your privacy intact as we go through this. I'll handle every aspect of the research data with care, though, and keep your privacy a priority every step of the way.

9. Will the research be published? Could I be identified from any publications or other research outputs?

The findings from the research will/may be written up *in a thesis/dissertation.* I would like your permission to use direct quotations [*but without identifying you*] in any research outputs.

10. Data Protection

The University of Oxford is the data controller with respect to your personal data, and as such will determine how your personal data is used in the research. The University will process your personal data for the purpose of the research outlined above. Research is a task that is performed in the public interest. Further information about your rights with respect to your personal data is available from the University's Information Compliance website at https://compliance.admin.ox.ac.uk/individual-rights.

11. Who has reviewed this research?

This research has received ethics approval from a subcommittee of the University of Oxford Central University Research Ethics Committee. (Ethics reference: **SOGE C1A 24 74)**.

12. Who do I contact if I have a concern about the research or I wish to complain?

If you have a concern about any aspect of this research, please contact *[Aji Wijaya Abadi on aji.abadi@oriel.ox.ac.uk*] or [*Dr Kevin Grecksch on kevin.grecksch@ouce.ox.ac.uk*], and we will do our best to answer your query. We will acknowledge your concern within 10 working days and give you an indication of how it will be dealt with. If you remain unhappy or wish to make a formal complaint, please contact:

the University of Oxford Research Governance, Ethics & Assurance (RGEA) team at rgea.complaints@admin.ox.ac.uk or on 01865 616480.

13. Further Information and Contact Details

If you would like to discuss the research with someone beforehand (or if you have questions afterwards), please contact:

[*Aji Wijaya Abadi*]
[*School of Geography and the Environment*]
[*OX1 3QY*]
University tel: [*+44 (0)1865 285070*]
University email: [*aji.abadi@oriel.ox.ac.uk*]

Appendix III: Oral Consent Form

Researcher record of oral consent template

Interviewee Name or Number (if anonymous participant):

Date:

Location (City / Region):

Project Explained (Yes/No):

Interview recorded or Notes Taken:

Participant agreed to direct quotes? (Yes / No):

Participant agreed to quotes which would not identify them? (Yes/No):

Participant is not to be quoted at all (Yes/No):

OPTIONAL: Signature of Researcher [Aji Wijaya Abadi]
(Signed in the presence of the interviewee to confirm oral consent):

SSH_IDREC reference: Template Researcher record of oral consent – Version 1, 25 September 2014

Appendix IV: Oral Consent Script

Introduction (*): Hello [again], my name is [Aji Wijaya Abadi]. I'm currently [a Master's student] at the University of Oxford in [School of Geography and the Environment].

- **Project details and aims**: In my study, I want to investigate [the intricacies of water service systems within coastal tourism areas and explore the challenges they face, particularly along the Gunungkidul coasts]. I'm interested in [interviewing local actors who live or have livelihoods in the coastal tourism area in the Gunungkidul coastline]. If you choose to be a part of this project, here is what will happen:
- **Interviews/ surveys/ tasks description**: I will [have a conversation with you for around 20 – 30 minutes] where I will ask a range of questions about [water use, water source, water supply, environmental impacts of water services, water accessibility, water affordability, water equity, water policy, water technology, water crises, water management, and WaSH aspects].
- **Data sharing/ access/ confidentiality**: The [answers/ data] you give will form the basis of my [MPhil dissertation].
  (*) On a practical level, the [researcher and/ or e.g. research team, supervisor, collaborator/ translator/ transcriber…] will have access to [research data].[1] [the research data is pseudonymised].
- **Data storage**: I will store your data safely and confidentially [in my One Drive] and will keep the research data for [5] years after publication.[2]
  (*) [If applicable] I would like to be able to use your de-identified data in future studies, and to share this data with other researchers.
- **Audio/ video recording/ photos/ notes**: With your permission, I would like to [make an audio recording of our discussion to make sure I'm getting an accurate record of the interview/ photograph you/ video record you]. Instead of recording you, I can take notes in my notebook. Which would you prefer?
- **How identifiable you will be**: [This research only acquires name of the research participants. They can choose either their name quoted directly, pseudonymised identifiable data as interviewees' personal information is pseudonymised, or not quoted at all].
- **Risks**: [Participants in this research are not expected to encounter any disadvantages or risks by participating]. You might find aspects of this interview [difficult/ distressing/ other] as I'll be asking for your opinions about [explain why]. In order to reduce any potential risks, [you can choose not to answer any questions they don't want to, pause for a break or stop the interview altogether].
- **Rights**: You don't have to take part; you can ask me any questions you want before or throughout; you can also withdraw at any stage of the [interview/ other activity] without giving a reason. After the [interview/ other activity] you can withdraw your information/ data until [(31/12/24) (i.e. before it is pseudonymised; before publication)].

[1] Please follow CUREC's Best Practice Guidance on Data collection, protection and management
[2] This should be a minimum of three years after publication according to University Policy, or longer depending on funder requirements.

- **Publication plans**: The project may/ will be published in a(n) [dissertation]. [For doctoral students or other qualifications or research where a thesis, dissertation or other research output needs to be published in the Oxford University Research Archive: A copy of my thesis/ dissertation, will be deposited both in print and online in the University archives.][3]
- **Complaints/ concerns procedure**: If you have any complaints or concerns please feel free to contact me. My phone number is [+6282243944459]. You can also reach me at [aji.abadi@oriel.ox.ac.uk].
- **Ethics review details**: This research project has been reviewed and approved by an Oxford University ethics committee. The ethics reference is [**SOGE C1A 24 74**]. If, after contacting me with any concern, you're still unhappy and wish to make a formal complaint, please contact the University of Oxford Research Governance, Ethics & Assurance (RGEA) team at rgea.complaints@admin.ox.ac.uk. [For applications reviewed by the Oxford Tropical Research Ethics Committee (OxTREC), please insert the contact details for the local ethics committee which has reviewed your study].
- (*) **Data Protection statement**: The University of Oxford is responsible overall for ensuring the safe and proper use of any personal information you provide, solely for research purposes. Further information about your rights to information you provide is available from the University's data protection website. [If research participants ask for more information, this is available here https://compliance.web.ox.ac.uk/individual-rights].
- **Questions/ concerns**: Do you have any questions?
- Do you give your permission for me to interview you/ take your photo/ video/ audio record you?
- Do you give me permission to quote you directly [using your real name/ without identifying you]?
- Are you happy to take part?

Ok, thanks, let's start.

[3] Oxford students following D.Phil., M.Litt. and M.Sc. (by Research) courses should refer to http://www.bodleian.ox.ac.uk/ora/oxford_etheses.

Appendix V: Interview Guidelines

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

Interview Guideline for Qualitative Data Collection

Water Services in the Coastal Tourism Zone of Gunungkidul Karst

Participant Category	Locals
Enumerator	Aji Wijaya Abadi
Date	, 2024
Time	: (UTC +7)
Location	
Name of Participant	
Number/Code	L

A. Opening Section

1. Do you live close to or far from the beach?
2. How long have you worked in this coastal attraction?
3. Are you a part of a tourism awareness community here? If so, what role do you take?
4. What kinds of water consumption are present in this area? Which are the majority?
5. How frequent is the water use? When do tourists use the most and the least water?
6. Are any water use limits established on this beach?
7. How is the water sourced for the tourism activities?

B. Main Section

B1: If the water is obtained from the regional water utility

1. How good is the water quality? Do you add further treatment before using it?
2. How sufficient and how reliable is the water supply?
3. What activities demand this water?
4. Have you ever found the utility unfair in delivering water services to your place? If so, how are disputes addressed?
5. Has the utility invited you to take part in any meetings or discussions addressing issues related to water services in coastal areas?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

B2: If the water is sourced by small-scale private providers

1. Can you elaborate on the whole process of sourcing and utilising water from this provider?
2. What do you think about the water quantity and quality?
3. How is this water allocated for coastal tourism?

B3: If the water is managed by a community-led program

1. Is the water supply available and consistent at all times?
2. How would you describe the water quality? Is there regular monitoring? If so, whose responsibility?
3. What activities use this water?
4. How do you access and utilise the water source?
5. How good is this source in terms of accessibility and affordability?
6. Has the water source ever shrunk or dried up? What measures to handle it?
7. Are there any sectors beyond tourism that demand the same source?
8. Have there been any types of pollution contaminating the water source?
9. Do you know whether a saltwater intrusion is threatening the water source?
10. Have the tidal wave dynamics ever destroyed the surrounding water infrastructure?
11. How to address any locals' complaints regarding the water services?
12. Has your community held any public meetings or gatherings to discuss on water issues?

C. Additional Section

1. Who plays the significant role of managing water in coastal tourism?
2. Are there any organisations advocating for sustainable water management in the coastal tourism sector?
3. Have you heard of any technological or infrastructure development plans in place to advance the water services on this beach?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

4. Are the locals continuously involved in any decision-making stages regarding the water management in the area?
5. Who controls the price of public bathroom and toilet services on the beach?
6. Are bathrooms and toilets separated?
7. How does your business dispose of the greywater and other water-related wastes? Which practice have you been doing–pre-treatment, temporary storage, or direct disposal?
8. Are there any wastewater treatment programs or facilities available to properly manage the wastewater resulting from the tourism activities?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

UNIVERSITY OF OXFORD

Participant Category	Hospitality Industry
Enumerator	Aji Wijaya Abadi
Date	, 2024
Time	: (UTC +7)
Location	
Name of Participant	
Number/Code	P

A. Opening Section

1. How long have you run this business?
2. Do you open opportunities for locals to work at your property?

B. Main Section

1. What is the primary water consumption, and how frequent is it?
2. How do you have the water access for your business? Is it drawn from one source or multiple sources?
3. What existing water issues have you ever encountered which impact your business?
4. Do you have any mitigation strategies in place to prepare for water emergencies? If so, could you elaborate on them?
5. What have you given back to the local community regarding your presence as an emerging tourist destination?
6. Do you have a particular technique to manage your waste, especially the wastewater?
7. Have you ever been invited by the local officials to attend discussions or meetings concerning water issues in your area?
8. Have you ever encountered social conflicts because of your business? If so, how have you resolved them?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

UNIVERSITY OF OXFORD

Participant Category	Water Utility
Enumerator	Aji Wijaya Abadi
Date	, 2024
Time	: (UTC +7)
Location	
Name of Participant	
Number/Code	G

A. Opening Section

1. How many units does this water utility manage? Does each branch serve a specific category of consumers, a designated area, or a certain sector?
2. Is every unit equipped with water treatment infrastructure?
3. Does the utility supply water beyond domestic use?

B. Production

1. How does each unit collect its water, and have any of their sources been unreliable, fluctuating, or drying up?
2. Have you ever faced a water emergency due to climate or weather factors that led to an inability to sustain your operation?
3. Since when has the utility been serving water for the tourism sector in coastal communities?
4. How significant is the current trend of water demand coming from the coastal tourism sector? Is this accelerated by the increasing customers from coastal communities?

C. Distribution

1. Does your utility have multiple distribution networks to transfer water to coastal areas?
2. What are the major issues in water distribution to coastal regions? Is the current distribution system effective?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

UNIVERSITY OF OXFORD

D. Management

1. Does the utility run at normal operation throughout the year, or should it deploy operational adjustments to adapt to any disruptions?
2. What water conservation practices are in place to safeguard the water source, and do your institutions encourage the implementation of sustainable water management on a local scale, especially the coastal tourism sector?
3. What is the main funding source that maintains your operation?
4. Do water tariff differ from one beach to another? What factors determine it?
5. Which consumer, households or tourism businesses are the most profitable, and how are the profits used?
6. Do you conduct routine monitoring and evaluation or give training that engages with the local community?
7. Have you ever received complaints from the coastal communities regarding the utility services, and how have you addressed them?

E. Future Development

1. Do you see any potential collaborations for partnerships or financing opportunities with other parties to boost or escalate your utility?
2. Are there any ongoing projects to enhance the productivity of the utility?
3. Is your institution related to the water pipes and storage aid given by the Ministry of Defence?
4. Has your institution considered and accounted the potential threat of climate change into your future plan?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

UNIVERSITY OF OXFORD

Participant Category	Local Tourism Office
Enumerator	Aji Wijaya Abadi
Date	, 2024
Time	: (UTC +7)
Location	
Name of Participant	
Number/Code	G

A. Opening Section

1. How significant is the coastal tourism growth in this regency?
2. What role does your institution play that reflects your participation in the planning and development of a water management system for coastal tourism?

B. Tourist Site Planning and Development

1. What paramount aspects do you account for in water provision when planning a tourist site development?
2. What is the tourism strategic zone meant for? Does its provision in the existing tourism master plan have a greater implication in accelerating tourism development projects? Does this include prioritisation of basic services programs such as clean water facilities?
3. Regarding the tourism strategic zone, how do you take advantage of this classification to debottleneck water services issues in coastal tourism?
4. Have you ever been involved in clean water projects in a coastal tourist destination alongside other stakeholders? What were the outputs, and have they considered the climate change challenges?
5. Are there any existing laws or policies in place which include the provision of sustainable water management practices in the coastal tourism sector?
6. Do you expect growth in tourist arrivals? How do you anticipate the consequences of it for the future of water demand and supply in this area?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

7. What action would you take to control the physical development happening in the coastal areas, such as seaside resorts?

C. Community Engagement and Empowerment

1. Have you ever had concerns, such as local protests or disputes with private developers over water resources utilisation in tourist sites? If so, how have you responded to it?
2. Do you assign certain budgets for the tourism community groups to improve their tourism facilities? If so, do you allocate to the improvement of water infrastructure or services quality?
3. Do you cooperate with the local government or other parties for community capacity building to achieve sustainable water management in coastal tourism?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

UNIVERSITY OF OXFORD

Participant Category	Local Environment Office
Enumerator	Aji Wijaya Abadi
Date	, 2024
Time	: (UTC +7)
Location	
Name of Participant	
Number/Code	G

A. Opening Section

1. What issues are your institution currently focused on in this region?

B. Environmental Monitoring

1. Have you committed to inventorying all water sources available in this region and classifying their properties? If so, whom did you work with?
2. Does your institution conduct regular monitoring of the water quantity and quality of every water source? What findings have you found regarding their status, especially the water sources near the coastal areas?
3. How is the implementation of waste management in coastal tourism areas? Have tourism activities raised concerns or posed environmental threats to the water sources nearby?
4. Do you monitor any karst land issues that may affect the sustainability of the water sources, and what strategies do you implement to protect them?

C. Policy Development and Community Empowerment

1. Are there any policies or regulations designed to conserve karst water sources? If yes, do they weigh the likelihood of climate-induced threats?
2. Has your institution ever carried out studies or established policies regarding water abstraction and wastewater disposal provision in a coastal tourist destination? Which stakeholders were you working with, and have the findings or results been enacted?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

3. Do you assist the local communities in applying sustainable water management practices in the coastal tourism sector?
4. Concerning the limited units of communal wastewater treatment facilities, are there programs or projects to resolve this problem? What obstacles have you experienced?
5. Do you have collaborative plans with the tourism office to establish a guideline or manual of sustainable coastal tourism which emphasises sustainable water use practices?
6. What measures have been prepared to tackle the impacts of climate change and ensure the water sources in the coastal zone?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

UNIVERSITY OF OXFORD

Participant Category	River Basin Organisation
Enumerator	Aji Wijaya Abadi
Date	, 2024
Time	: (UTC +7)
Location	
Name of Participant	
Number/Code	G

A. Opening Section

1. Could you describe how the water supply system works in this regency?

B. Water Source

1. What forms of karst water sources are considered highly promising in terms of their availability, reliability, and accessibility, and which sources are very sensitive to any potential threats? How are they determined for the water supply?
2. Do you operate aquifer recharge mechanisms?
3. Do you think the existing water services in coastal areas are already effective and sustainable, or do you have any ideas what system is better?
4. What is the most influential factor that affects the water sources' sustainability?

C. Management

1. Do you observe notable differences in the development of water systems between inland and coastal areas, and which stakeholders are you working with in this process?
2. Does your institution issue manuals or guidelines to control water use and promote sustainable water management in the coastal areas? If so, have they been circulated to the locals, particularly those working in coastal tourism? Do you collaborate with other stakeholders to encourage this?
3. Does your institution actively promote water conservation implementation in coastal tourism?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

4. In what ways has your institution conducted regular monitoring and evaluation of the current water supply system in this region?

D. Impacts of Coastal Tourism

1. Do you have concerns about the practice of open-bottom wastewater disposal in coastal tourist destinations?
2. Are there plans in place to help the coastal communities improve the wastewater management infrastructures?

E. Future Challenges and Adaptations

1. Do you have upcoming projects that consider the potential impacts of climate change towards the existing water resources?
2. Is your institution aware of the locally driven water supply infrastructures? Do you have plans to enhance these systems?
3. Do you see any other feasible alternatives to support the current water supply? Is desalination included in your future options?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

UNIVERSITY OF OXFORD

Participant Category	Non-Governmental Organisation
Enumerator	Aji Wijaya Abadi
Date	, 2024
Time	: (UTC +7)
Location	
Name of Participant	
Number/Code	N

A. Opening Section

1. How long have you been focusing on issues in the karst region?
2. Could you explain the most critical issues that you have been advocating for?

B. Research and Knowledge

1. Have you ever assisted the respective stakeholders with water sources or pollution data inventory in the region?
2. How would you describe the nature of water management between inland communities and coastal communities?
3. What is your take on the rising coastal tourism? Have you ever observed any complaints or conflicts from the locals due to the presence of private developers?
4. How do you take part in coastal tourism water resource management?

C. Advocacy, Community Engagement, and Capacity Building

1. Have you started fostering climate-resilient community-based water management?
2. Have you cooperated with relevant stakeholders to encourage sustainable water management amongst the local communities in coastal tourism industries?
3. Have you been involved in supporting basic water infrastructure provision and wastewater management improvement in the coastal tourism sector?
4. Which stakeholders have you successfully worked with in addressing water problems in coastal areas?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

UNIVERSITY OF OXFORD

Participant Category	Academia
Enumerator	Aji Wijaya Abadi
Date	, 2024
Time	: (UTC +7)
Location	
Name of Participant	
Number/Code	A

A. Opening Section

1. Since when have you actively studied the water issues in the karst landscape?
2. What kind of complaints have you heard about from the coastal communities regarding their water issues?

B. Research and Knowledge

1. Have you found any significant fluctuations in underground river streams through your research journeys in Gunungkidul karst?
2. Based on your understanding of the karst systems, do you think that the flourishing of local water services in the coastal areas could potentially disrupt the karst hydrology systems?
3. To what extent do you believe that conventional wastewater disposal in coastal areas could damage the karst hydrology?
4. Has your research experience led you to witness or discover any climate change omens happening throughout the water sources in the karst region that we should anticipate?
5. Have you disseminated these findings to the corresponding stakeholders for the decision-making that highlights its significance to water services in coastal tourism?

C. Community Engagement and Policy Development

1. Has your institution taken part in any collaborations to establish water facilities for the coastal communities?

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

Course Director: Dr Kevin Grecksch
Email: kevin.grecksch@ouce.ox.ac.uk

OUCE, South Parks Road, Oxford OX1 3QY United Kingdom
Tel: +44(0)1865 275887 Fax: +44(0)1865 275885

MSc Course Coordinator: Faith Opio, msc-coordinator-ecm-wspm@ouce.ox.ac.uk

2. Has your institution been invited to participate in policy-making or decision-making with the corresponding stakeholders?
3. Has your institution encouraged the implementation of sustainable water management as a part of educating the coastal communities in the karst region?