Overall Grade: 28 (A). This Earth System Study exemplifies IAE1 at the A standard, including detailed justification

Performance Standards for Stage 2 Earth and Environmental Science

	Investigation, Analysis, and Evaluation	Knowledge and Application
A	Critically deconstructs a problem and designs a logical and coherent earth and environmental science investigation with detailed justification. Obtains, records, and represents data, using appropriate conventions and formats accurately and highly effectively. Systematically analyses and interprets data and evidence to formulate logical conclusions with detailed justification. Critically and logically evaluates procedures and their effect on data.	Demonstrates deep and broad knowledge and understanding of a range of earth and environmental science concepts. Applies earth and environmental science concepts highly effectively in new and familiar contexts. Critically explores and understands in depth the interaction between science and society. Communicates knowledge and understanding of earth and environmental science coherently, with highly effective use of appropriate terms, conventions, and representations.
B	Logically deconstructs a problem and designs a well-considered and clear earth and environmental science investigation with reasonable justification. Obtains, records, and represents data, using appropriate conventions and formats mostly accurately and effectively. Logically analyses and interprets data and evidence to formulate suitable conclusions with reasonable justification. Logically evaluates procedures and their effect on data.	Demonstrates some depth and breadth of knowledge and understanding of a range of earth and environmental science concepts. Applies earth and environmental science concepts mostly effectively in new and familiar contexts. Logically explores and understands in some depth the interaction between science and society. Communicates knowledge and understanding of earth and environmental science mostly coherently, with effective use of appropriate terms, conventions, and representations.
C	Deconstructs a problem and designs a considered and generally clear earth and environmental science investigation with some justification. Obtains, records, and represents data, using generally appropriate conventions and formats, with some errors but generally accurately and effectively. Undertakes some analysis and interpretation of data and evidence to formulate generally appropriate conclusions with some justification. Evaluates procedures and some of their effect on data.	Demonstrates knowledge and understanding of a general range of earth and environmental science concepts. Applies earth and environmental science concepts generally effectively in new or familiar contexts. Explores and understands aspects of the interaction between science and society. Communicates knowledge and understanding of earth and environmental science generally effectively, using some appropriate terms, conventions, and representations.
D	Prepares a basic deconstruction of a problem and an outline of an earth and environmental science investigation. Obtains, records, and represents data, using conventions and formats inconsistently, with occasional accuracy and effectiveness. Describes data and undertakes some basic interpretation to formulate a basic conclusion. Attempts to evaluate procedures or suggest an effect on data.	Demonstrates some basic knowledge and partial understanding of earth and environmental science concepts. Applies some earth and environmental science concepts in familiar contexts. Partially explores and recognises aspects of the interaction between science and society. Communicates basic earth and environmental science information, using some appropriate terms, conventions, and/or representations.
E	Attempts a simple deconstruction of a problem and a procedure for an earth and environmental science investigation. Attempts to record and represent some data, with limited accuracy or effectiveness. Attempts to describe results and/or interpret data to formulate a basic conclusion. Acknowledges that procedures affect data.	Demonstrates limited recognition and awareness of earth and environmental science concepts. Attempts to apply earth and environmental science concepts in familiar contexts. Attempts to explore and identify an aspect of the interaction between science and society. Attempts to communicate information about earth and environmental science.

Word count: 1,995

Question: Is the agistment of horses at Breakout Creek (River Torrens outlet) adversely affecting the water quality of the River Torrens, which is currently a contributing factor to the seagrass dieback in St Vincent Gulf?

Proposal

Outline includes detailed justification of proposal

Outline

This study will focus on the possible detrimental change to water quality nutrient levels of the River Torrens' water at Breakout Creek, which enters St Vincent Gulf (hydrosphere), due to the agistment of horses along this riparian zone (biosphere). To compare how the water nutrient levels change, two sections of Breakout Creek will be monitored by collecting water samples – both upstream and downstream of the horse agistment area (Image 1). This primary data will be gathered every 2-3 weeks from April to July 2022. The nutrient to be monitored is phosphorus. Phosphorus is prevalent in horse faeces and urine (Westendorf, M., 2004) (Image 2) and is a primary contributor to the dieback of seagrass (biosphere) in St Vincent Gulf (Westphalen, G., 2005). The major cause of seagrass dieback is increased growth of epiphytes (biosphere) on seagrass leaves (Hwang, C., 2019) (Image 3). Epiphytes in St Vincent Gulf have had increased growth due to higher nutrient levels of ammonium, nitrate, and phosphorus in the water, which promote epiphyte growth (Bryars, S., 2011). Epiphytes attach to seagrass leaves, which: reduce light levels by 30-60% resulting in a reduction of seagrass photosynthesis; restrict gas exchange; compete for nutrients; cause thinning of shoots; create breakage of leaves due to dragging weight; and ultimately result in seagrass death (Harbison, P., 1997; Seddon, S., 2000; Hwang, C., 2019; Westphalen, G., 2005).

The protection of seagrasses is fundamental to the marine ecosystem. They are the primary foundation for the food chain, providing shelter and a food source for small crustaceans, fish, worms, and shellfish (Harbison, P., 1997). The decline of these species will result in the eventual decline of their larger predator fish species. Furthermore, seagrass meadows protect sand from shifting along St Vincent Gulf, which is a significant issue for South Australia (Gaylard, S., 2013; *Department for Environment and Water, 2021*).

In-text references are not included in the word count.

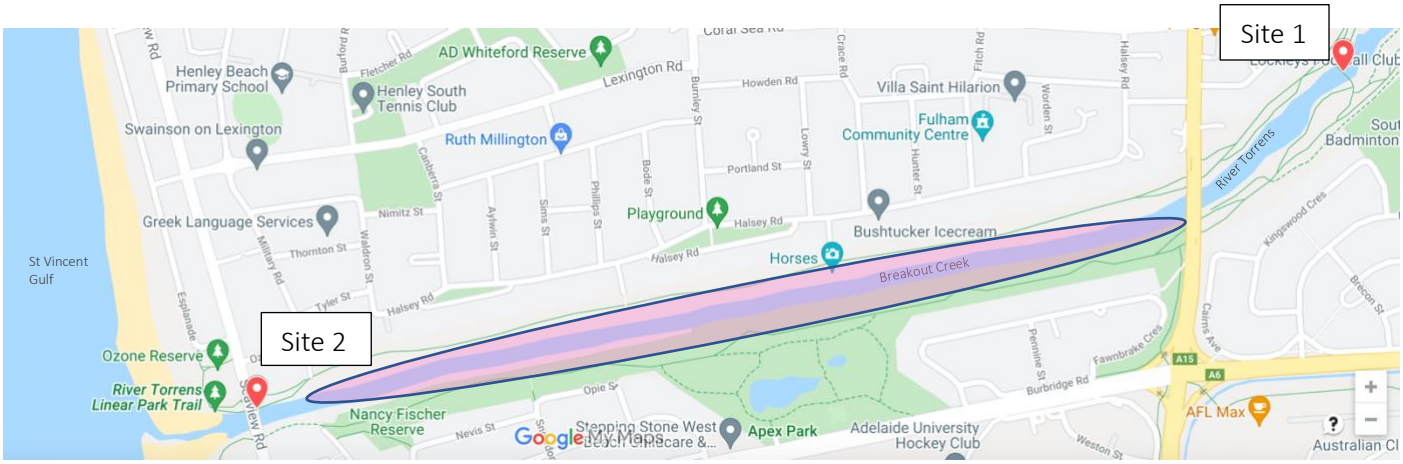


Image 1: Map of water sample collection sites (*Google Maps*, 2022)

Breakout Creek collection sites
Horse agistment area shaded in pink





Image 2: Riparian zone of Breakout Creek, horse faeces (left), and damaged grass due to horse urine (right) (student's own)



Image 3: Healthy *Posidonia* Seagrass (left), with epiphyte growth (centre), and seagrass loss (right) (Environmental Protection Agency, 2009)

Data Collected

Primary quantitative data will be collected by measuring and recording phosphorus in the water samples. Secondary quantitative data will be collected regarding total rainfall in the Adelaide area over the prior three days to each water sample collection, from the Bureau of Meteorology (http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=023000) (*Bureau of Meteorology, 2022*). This may assist in analysing the data as rainfall increases nutrient loads in the catchment area due to rural and urban stormwater runoff entering the river system (Croke, J., 2002).

Equipment

- 1 x phosphorus monitor (Image 4)
- 4 x 100ml plastic sample containers
- 9L bucket tied to 4m of rope
- 1 x safety glasses
- 1 x box of disposable vinyl powder-free gloves
- 1 x lab coat
- 1 x computer with spreadsheet of Table 1
- 500mL bottled tap water (refer to Risk Assessment for use)
- 60mL bottled hand sanitiser (refer to Risk Assessment for use)



Image 4: phosphorus monitor (student's own)

Table 1: Suggested table for recording phosphorus levels and rainfall data

		Phosphorus (ppm) (1dp)	
Date of Collection	Total Rainfall Over Prior 3 Days (mm) (one decimal place (1dp))	Site 1: upstream from horse area	Site 2: downstream from horse area

The list of equipment/materials is included in the word count.

Procedure

1) Collect water, filling two sample containers, from Site 1 (Image 5) – River Torrens footbridge, upstream from horse area at coordinates (34°55'46.0"S, 138°31'13.7"E) (Image 1). Collecting water upstream from horse area (Site 1) will provide a control value to compare against water collected downstream from horse area (Site 2). Although one sample container will be used for phosphorus monitoring, a second container will be used as a backup.
2) Collect water from Site 2 (Image 6) – Breakout Creek, downstream from horse area, but before the weir, at coordinates (34°56'05.6"S, 138°29'56.8"E) (Image 1). To collect water – from the elevated footpath, lower bucket by rope into the creek and fill with water. Fill two sample containers with water collected in bucket. Collecting water before the weir ensures that seawater does not contaminate river water.
3) Return to lab for phosphorus monitoring. Wear safety glasses, gloves, and lab coat. Shake sample container from Site 1 and complete phosphorous monitor process referring to instructions (Image 7). Record phosphorus level in Table 1. Shaking ensures any sediments (possibly containing phosphorus) are evenly distributed before monitoring to obtain accurate results.
4) Repeat step 3 for the water collected from Site 2.
5) Repeat steps 1-4 every 2-3 weeks over April-July. Collecting data every 2-3 weeks for four months will help demonstrate trends over time and reduce the effect of random errors.
6) Collect rainfall data of prior 3 days for each sample date from Bureau of Meteorology (http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=023000) (Bureau of Meteorology, 2022), and add up the total rainfall of the 3 days; record in Table 1.

The method designed by the student is included in the word count, including justification as shown above.



Image 5: Site 1, upstream from horse area (student's own)



Image 6: Site 2, downstream from horse area (student's own)

The instructions shown in the image below is additional information beyond the method designed by the student and is not included in the word count.

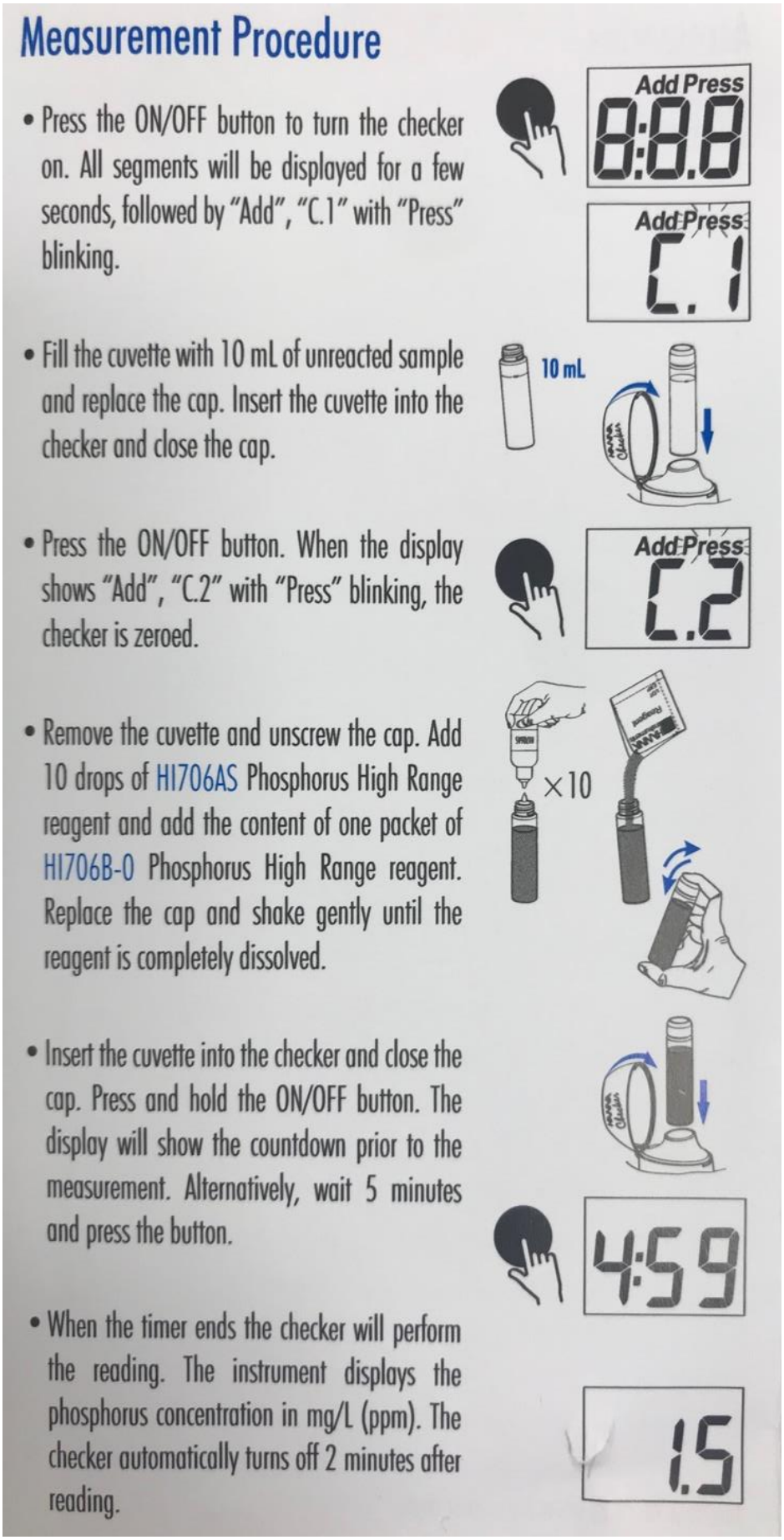


Image 7: Phosphorus monitor instructions (HANNA instruments, no date)

Risk Assessment

Risk	Identification	Management
Safety: River water	River Torrens is polluted water. Polluted stormwater flows directly into the river (*Green Adelaide, 2022)*.	Do not fall into or consume the water. Ensure paths are stable when collecting water samples. Bring a bottle of tap water and hand sanitiser when collecting water samples; if river water contacts skin, wash with bottled water, and use hand sanitiser.
Safety: Chemicals in phosphorus monitor	Phosphorus monitor uses chemicals to determine phosphorus level. These could be harmful if they come into contact with eyes or skin.	Always wear safety glasses, gloves, and lab coat during use of monitor. If chemicals do come into contact with eyes or skin, wash eyes and skin thoroughly with water from lab's eye-wash station or sink.
Ethics: Obstructing pathways	Pathways are public access areas. Do not obstruct others when collecting water samples.	Use minimal space. Be considerate of other users of pathway.
Legal: As the land and water are public access areas, there are no legal considerations.		

The risk assessment table is included in the word count

Report

Introduction

Seagrass meadows along St Vincent Gulf have been declining and are estimated to have lost over 5000 hectares since 1935 (*PARLIAMENT OF AUSTRALIA,* no date), as seen in Figure 1. This decline has been associated with increased epiphyte growth on seagrasses due to higher concentrations of phosphorus in the water (Bryars, S., 2011; Westphalen, G., 2005). Phosphorus cycles through the geosphere, hydrosphere, and biosphere. Phosphorus is mainly located in rocks and sedimentary deposits (geosphere) and is released through weathering into soils (geosphere) and water (hydrosphere) (*Encyclopedia Britannica,* 2020). Plants (biosphere) will take up phosphorus in the soil and water, promoting growth, and will convert this phosphorus into organic molecules (*Science Learning Hub,* 2013). Phosphorus will then be taken up by animals (biosphere) when they consume the plants or water (Bear, R., no date). Animal excrements, and decaying flora and fauna, will return the phosphorus to the soil (Bear, R., no date); thus, the phosphorus cycle (shown in figure 2) between the organisms and the soil continues (*Biology Dictionary,* 2017). Phosphorus can also enter bodies of water (hydrosphere) due to surface runoff and leaching, which can be taken up by aquatic organisms such as epiphytes and seagrasses (biosphere) (*Understanding Global Change,* 2020). Additionally, phosphorus in waterbodies can be incorporated into sediments, resulting in sedimentation and rock formation (*Science Learning Hub,* 2013).

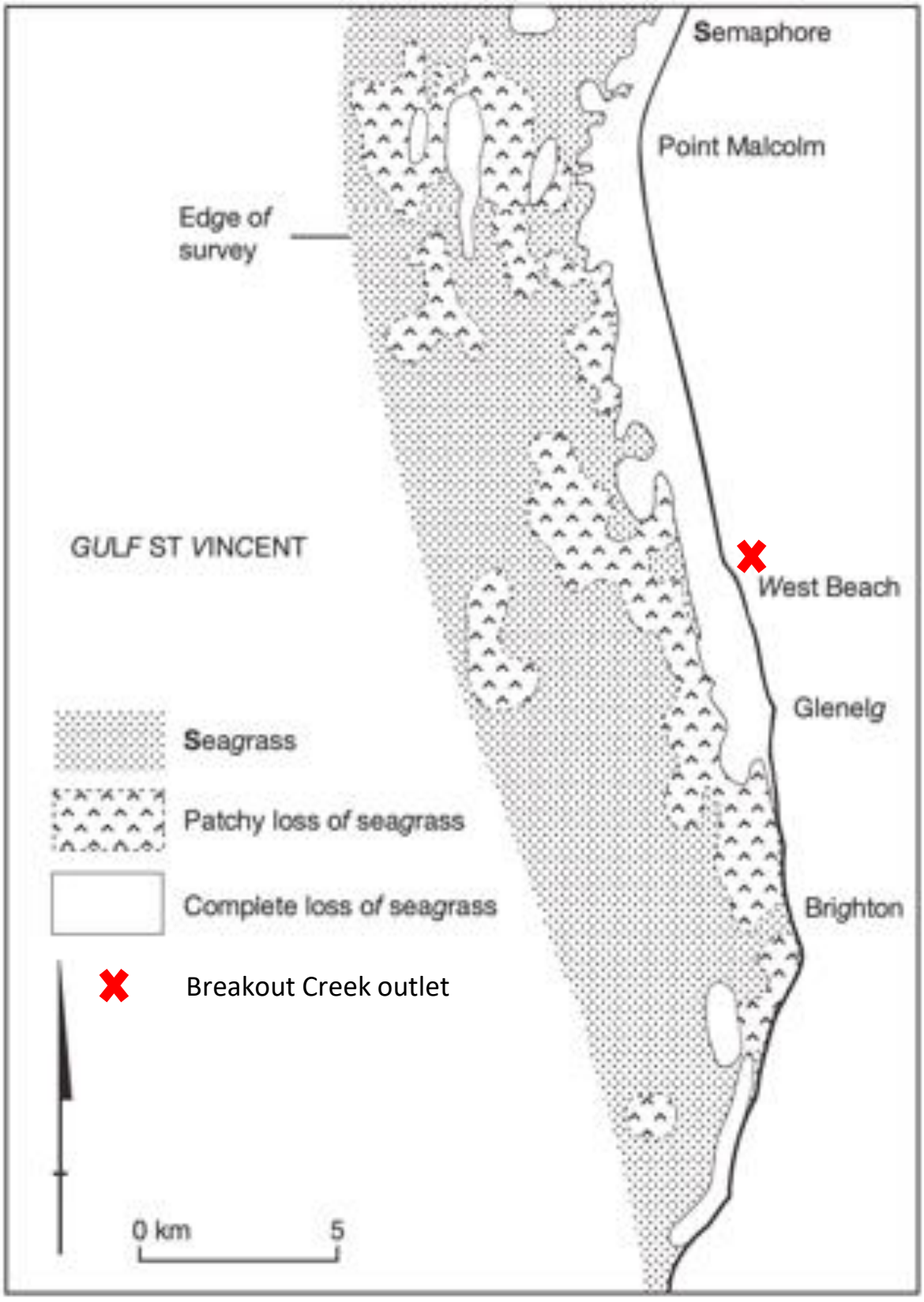


Figure 1: Seagrass recession in St Vincent Gulf (Harvey, N., 2010)

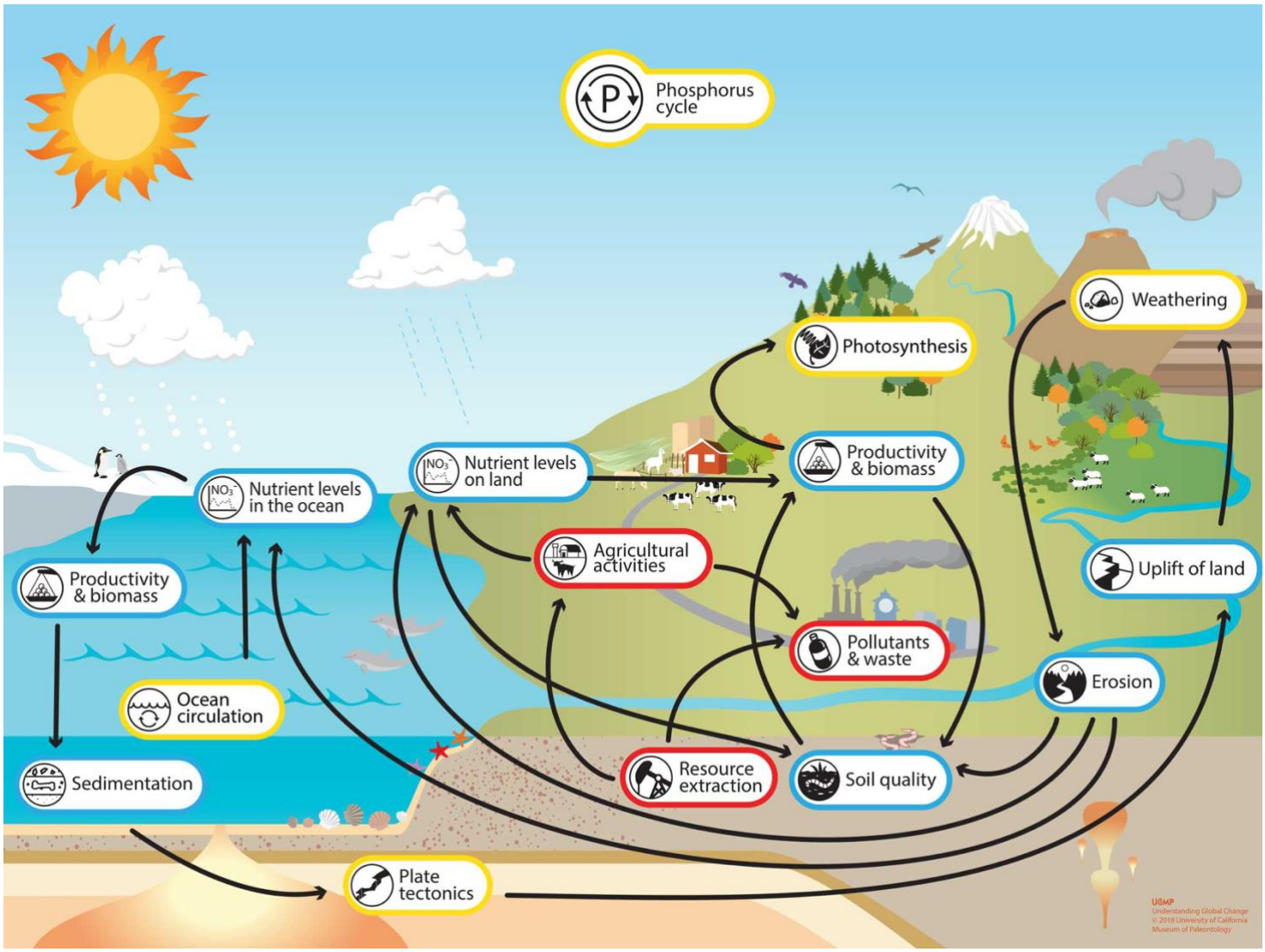


Figure 2: The phosphorus cycle (*Understanding Global Change,* 2020)

Labels on figures/images/diagrams as as shown above are not included in the word count. Note: if labels include explanations or analysis of the figure then this would be included as part of the word count.

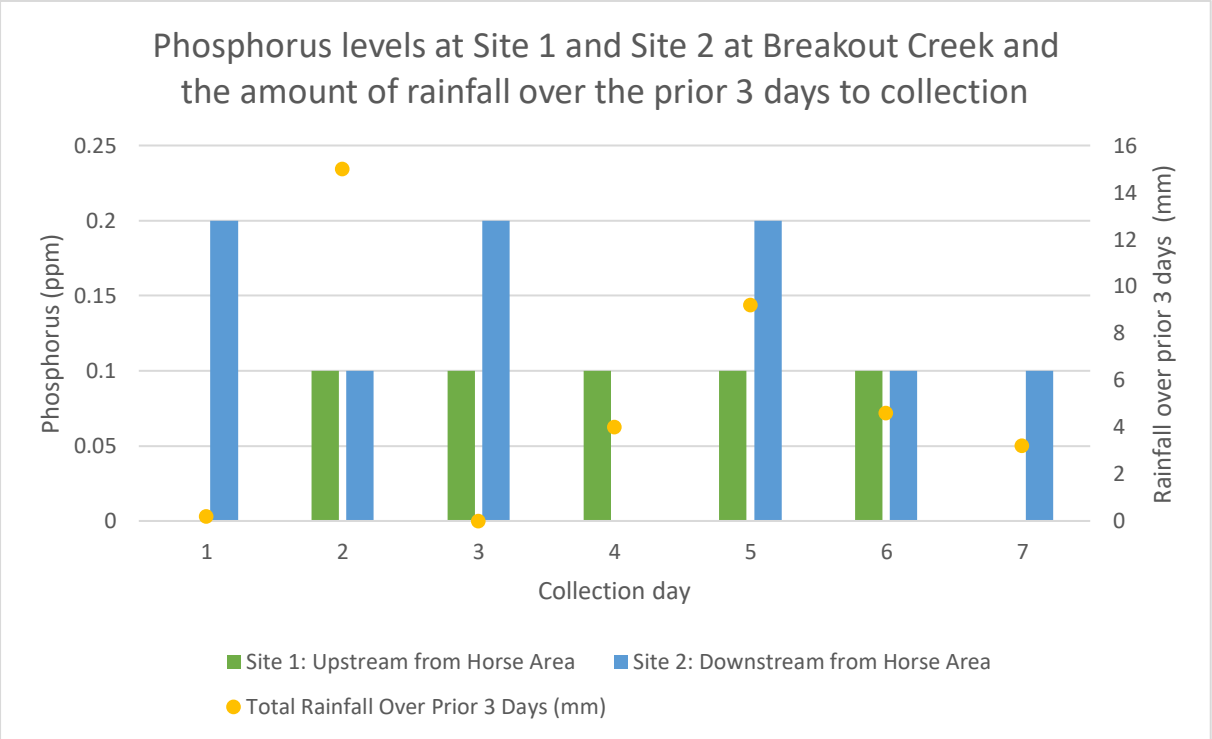
Results

Table 2: Phosphorus levels and rainfall data collected over four months, April-July 2022, from the two collection sites at Breakout Creek

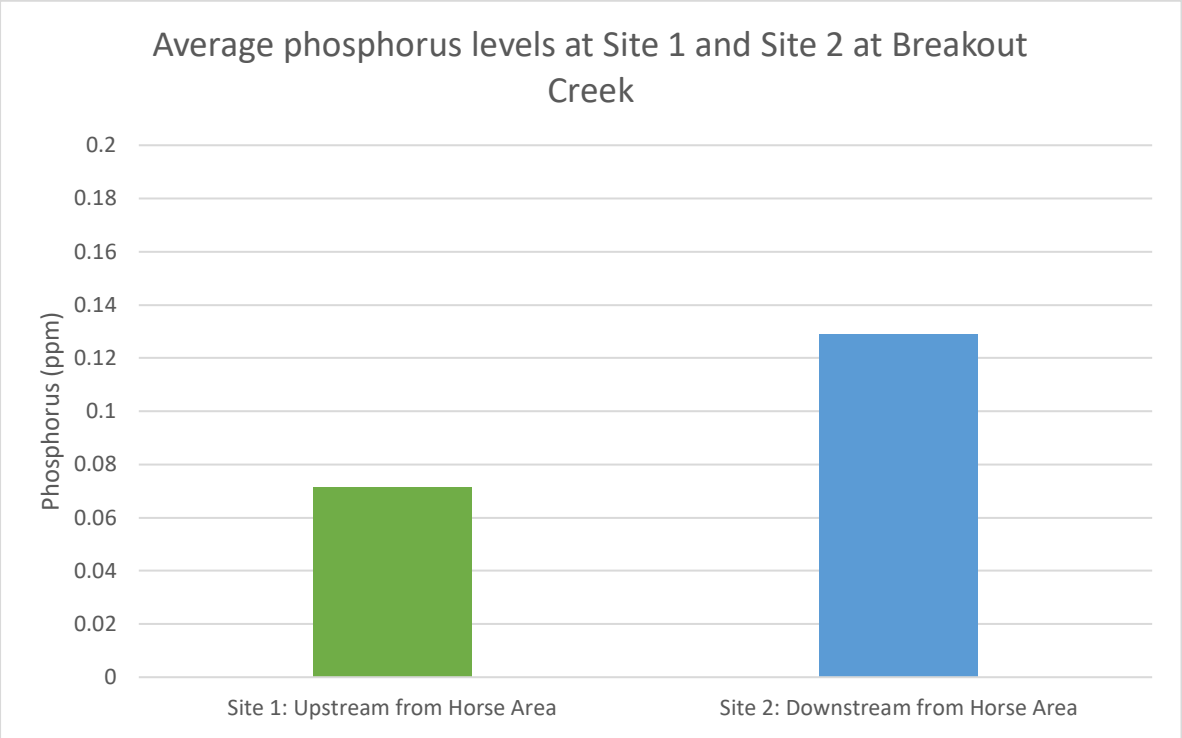
		Phosphorus (ppm) (1dp)	
Date of Collection	Total Rainfall Over Prior 3 Days (mm) (1dp)	Site 1: upstream from horse area	Site 2: downstream from horse area
17/04/2022	0.2	0.0	0.2
08/05/2022	15.0	0.1	0.1
22/05/2022	0.0	0.1	0.2
05/06/2022	4.0	0.1	0.0
18/06/2022	9.2	0.1	0.2
02/07/2022	4.6	0.1	0.1
16/07/2022	3.2	0.0	0.1
	Average phosphorus (ppm) (2dp):	0.07	0.13

Graphs, tables, data, labels and titles as shown on this page are not included in the word count. Note: if data tables include explanations or analysis of data then this would be included as part of the word count.

Graph 1



Graph 2



Analysis

Phosphorus levels at Site 2 are frequently the same as, or higher than, Site 1. From Graph 1, Site 2 commonly had a greater phosphorus concentration, with the largest difference between sites on the same collection day being 0.2ppm occurring on Day 1 (as also seen in Table 2). From Graph 2, the average phosphorus levels were 86% higher at Site 2 than Site 1, as determined from the calculation $\frac{Site\ 2\ average - Site\ 1\ average}{Site\ 1\ average} \times 100$. Hence, the horses appear to negatively impact the water phosphorus levels. Finally, from Graph 1, the amount of rainfall over the prior three days per collection day had no visible correlation to the phosphorus levels. Thus, over the short term, the data does not appear to be impacted by the nutrient load in stormwater runoff entering the river system or the possible nutrients washing down from the banks into the river.

Sphere Connections

From the above data, it appears that the horses (biosphere) have a negative effect on the water phosphorus levels in Breakout Creek (hydrosphere). As the water enters St Vincent Gulf (hydrosphere), this increase in phosphorus would contribute to epiphyte growth (biosphere), leading to seagrass (biosphere) decline.

Biosphere

Other land and aquatic animals (biosphere) may have been contributing to phosphorus levels in the creek (hydrosphere) due to their excrements or death in the water (Bear, R., no date). For example, pigeons roost underneath a bridge above the creek, and their faeces may have increased phosphorus levels in the water.

Hydrosphere

A contributing factor that may affect phosphorus levels in Breakout Creek could be the amount of rainfall (hydrosphere). Rainfall in the upstream farmland catchment areas of the River Torrens may have brought down phosphorus in the water. Furthermore, rain may wash the horse excrements located along the riparian zone into Breakout Creek. Finally, stormwater runoff from city streets may contain phosphorus and would enter the river system through stormwater outlets into the creek. While the data shows rainfall to not affect phosphorus levels in the creek within the short-term three-day period, it may affect the creek in the long term. However, this would require further research and investigation.

Geosphere

The horses' excrement, having built up over 87 years since horse agistment began (*Lockley's Riding Club inc.,* no date), may have penetrated the riparian zone (geosphere). Buried horse carcasses (seen exposed due to earthworks, Image 8) may also increase phosphorus soil levels. Phosphorus may be entering the creek (hydrosphere) due to it leaching out of the soil over time with the action of rainfall (hydrosphere).



Image 8: Earthworks at Breakout Creek exposing horse remains (student's own)

Evaluation

A limitation of the study was that Site 2 was located after a stormwater outlet which had the potential to increase the phosphorus levels in the creek due to suburban runoff, possibly containing a high nutrient load. A further limitation was that a redevelopment project began along Breakout Creek, which would have exposed trapped horse excrements and nutrients in the soil, possibly adding to the phosphorus levels in the creek more than the usual amount. An improvement to the study would be to sample water from multiple points around the two collection sites (Image 9) to determine an average phosphorus level at both sites, reducing the effect of random errors. Additionally, free-flowing water should be collected from the centre point of the creek's width using the footbridge at Site 1 and the car and pedestrian bridge at Site 2. This would reduce the chance of collecting stagnant water found at the edge of the creek, which may contain a higher phosphorus load (*United States Environmental Protection Agency,* 2022), thus not accurately reflecting the overall phosphorus levels of that section of the creek. It is also known that epiphytes grow excessively due to high levels of ammonium and nitrate (Bryars, S., 2011); these nutrients are also present in horse excrements (Westendorf, M., 2004). Hence, an improvement to the study, to more definitively determine if the horses are having the primary impact on the increased phosphorus levels, would be to see if there are also increased ammonium and nitrate levels in the creek.

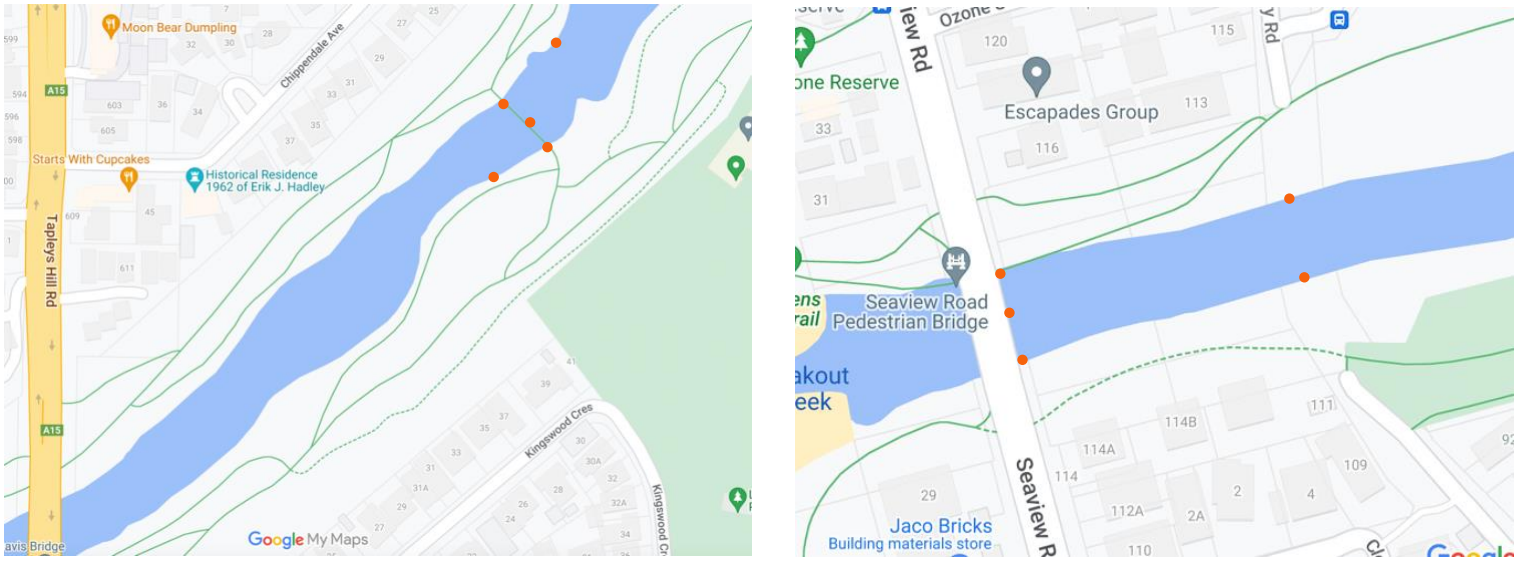


Image 9: Suggested additional sample points for further studies (*Google Maps*, 2022)

- Site 1 upstream from horse area, multiple locations (left)
- Site 2 downstream from horse area, multiple locations (right)

Random errors may have occurred during the phosphorus analysis, affecting the precision of the results. Due to the high sensitivity of the phosphorus monitor, the cuvette containing the sample water must be dry on the outside and free of fingerprints, oil, and dirt, to produce precise readings. Hence, random errors may have occurred if this criterion was not met for all samples. An improvement would be to wipe down the cuvette with a microfibre cloth each time before inserting it into the monitor.

Systematic errors may have occurred during the phosphorus analysis impacting the accuracy of the data. The phosphorus detector required a powder reagent to be added to the water and completely dissolved to detect phosphorus levels. However, for all samples, the reagent could not be dissolved entirely, possibly due to the cold-water temperature of the samples which were collected during winter. Hence, the results may have been skewed to be higher or lower than their true phosphorus levels. An improvement could be raising the samples to room temperature by leaving them in a warm room prior to monitoring.

Conclusion

This study indicates that the horse agistment along Breakout Creek negatively impacts the phosphorus levels of the River Torrens' outlet water and would thus contribute to the seagrass decline in St Vincent Gulf. Due to the increase in phosphorus levels after the horse agistment area, a higher load of phosphorus would be present in St Vincent Gulf waters, coinciding with the rise in epiphyte growth on the seagrass and the seagrass dieback. However, it is noted that only one nutrient, phosphorus, was analysed, while it is known that multiple nutrients present in horse excrement impact epiphyte growth.

The bibliography is not included in the word count

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If an appendix is included, this is not considered as part of the assessment