Pool and Bench Vegetation of Goodamon Creek (previously known as Stream E), Ginninderry Conservation Corridor: Spring 2022

Chen-Yang Tsai

Feb 2023

Table of Contents

Summary

This survey (the fourth repeat survey) followed the same protocols and methods described in *Pool and Bench Vegetation of Stream E, Ginninderry: Baseline in Spring* 2018 (Roberts and Sharp 2019). To make this report more concise, three indicators (Annuals, Grasses, and Nativeness) and two parts (Evaluation and Bench floristics) were excluded from this report. The other indicators were chosen because they are expected to respond to urbanisation effects on stream hydrology and water quality.

The field study was conducted in Goodamon Creek, which takes its name from the Ngunnawal language, meaning Turtle Creek.

The water flow in Goodamon Creek (2022) was generally slower and clearer than in 2021 overall. The surrounding vegetation on benches and mudflats in 2022 was less dense than the previous year.

For the pools, the total depth of each pool in 2022 was generally deeper than the previous two years, this was likely due to a significant rainfall event on the 4th of August (72mm in Ginninderra district within 24 hours) (Domensino, 2022) and above average rainfall in October. Conversely, the depth of unconsolidated sediment was slightly shallower than last year, with more sediment accumulating in the upstream and downstream sites. Additionally, the area of tall emergent macrophytes in 2022 was significantly lower than in 2021, with no significant change in their height. It is important to note that no submerged macrophyte species were found in 2022, which may be caused by downpours, erosion, and livestock activities in downstream sites.

For the benches, grasses remained the dominant vegetation, while grazing and pugging had an even more severe impact than the previous year, particularly in downstream sites. The 2022 bench quadrat survey identified 20 dominant species and 5 new native species, which may indicate a positive shift in the local ecology. Perennials had a higher percentage in downstream sites, whereas upstream sites showed more annual coverage.

1. Pool and bench vegetation survey of Goodamon Creek (2022)

1.1: Background

This is the fourth repeat survey of vegetation of Goodamon Creek. Design and rationale for this survey, and results of the Baseline Survey in October- November 2018, are given in *Pool and Bench Vegetation of Stream E, Ginninderry: Baseline in Spring* 2018 (Roberts and Sharp 2019).

This report uses the same lay-out as previous monitoring reports (Roberts and Sharp 2020). Results are in two sections (Section 2: Pools; Section 3: Benches). In this report, Sections 2 and 3 now have a short description of the Method, immediately before each set of Results. Evaluation against targets (Section 4 in the previous monitoring report) is not included, as this report focuses on comparing data between three different years (2020, 2021, and 2022) and aims to make this version more concise.

Vegetation is monitored on two geomorphic features of Goodamon Creek: pools and benches. As these are where vegetation changes are likely to occur in response to upstream development. For practical reasons, runs (which are a third geomorphic feature of Goodamon Creek) were not included.

This survey uses two qualitative indicators (reference photos and impact gradient) and seven quantitative indicators. For qualitative indicators, the previous studies revealed that large animals cause impacts on pools and bench edges, so grazing effects and physical damage will be added in this report as one of qualitative indicators (present as impact gradient). On the other hand, the seven quantitative indicators, including vegetation height, dominant species, quadrat cover (%), pool depth (cm), tall emergent macrophytes area (m^2), submerged macrophytes area (m^2), and average height of tall emergent macrophytes (cm), were chosen because they are expected to respond to urbanisation effects on stream hydrology (increased discharge, faster flows, fewer dry spells) and water quality (sediment load). In this report, the measurement of nativeness (%), which was used as a quantitative indicator in the previous years, had been omitted as it was deemed unnecessary after two consecutive years of monitoring.

The raw data was recorded on the data sheets in the field survey and then transferred to an Excel file where average and standard deviation (referred to as **SD** in this report) were calculated. All the charts in this report were plotted by the programming language Python by importing pyplot (Matplotlib), seaborn, and pandas modules.

1.2: Study sites and Conditions

Study sites: The field study was conducted in Goodamon Creek which takes its name from the Ngunnawal language, meaning Turtle Creek. This stream is among several short and steep waterways in the Ginninderry Conservation Corridor, ultimately flowing into the Murrumbidgee River. In this survey, nine sites were sampled along Goodamon Creek: with the most upstream site being E01 (-35.22745, 148.98026) to the most downstream site being E32 (-35.22761, 148.96894) (Figure 1).

Figure 1. The nine study sites along Goodamon Creek (marked in blue).

Survey Team and Timing: The team in 2022 comprised Bridie Noble, Chen-Yang Tsai, Emily Fryett, Tyson Powell and Violet Marriott. Field work was done on one day (24 November) and each from morning to mid-afternoon, which was one week later than the last survey (on 15 November to 16 November 2021). These dates conform to the mid-spring timeframe recommended in the Baseline report.

Conditions: Rainfall is often a crucial factor in determining water depth and vegetation growth. The rainfall in 2022 showed no significant deviation from the last two years (Figure 2). From June to November in 2022, a total of 494.2mm of rainfall was recorded, which was slightly less than the 535.2mm recorded in 2021, but slightly higher than the 454.4mm recorded in 2020 (Figure 2). In 2022, the highest levels of rainfall were recorded in August and October when significant rainfall events impacted many waterways in the Corridor. However, November, the month in which the survey was conducted, saw lower total rainfall compared to the previous year (Figure 2).

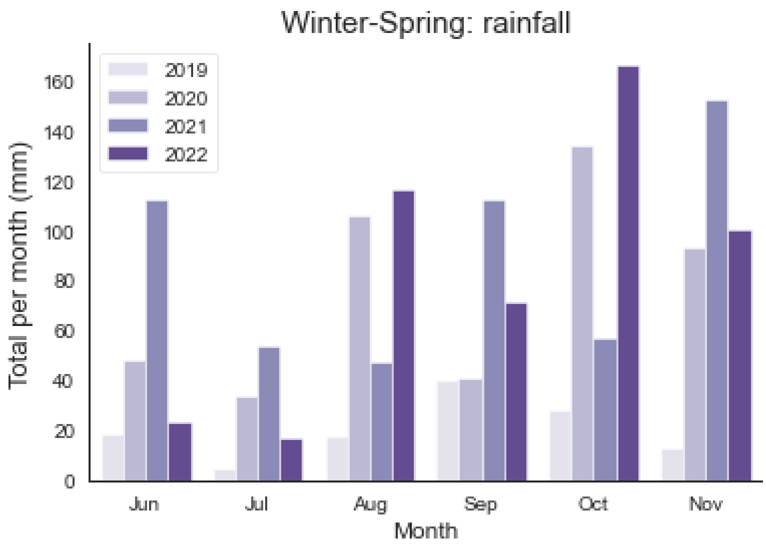


Figure 2. Winter to spring rainfall from 2019 to 2022 (Station 070351, Bureau of Meteorology)

Several anthropogenic factors affecting the pool and bench environment of Goodamon Creek in 2022 are worthy to consider: Construction of the new suburb Macnamara began June 2022, with the border running in close proximity to some of the upstream sites of the creek and a dam within -the border of Macnamara, was drained just before the survey on 11th November and flowed into Goodamon Creek (between E26 and E28), which likely had some impact on the last two sites (E28 and E32).

The sediment depth in rivers or creeks may be affected by various natural factors, for examples, erosion (Duodu, Goonetilleke, & Ayoko, 2017), terrain (Wang, Yan, Wen, & Chen, 2016), and water flow (Gupta and Chakrapani, 2005). Further research is necessary to determine the primary drivers of sediment depth change in Goodamon Creek.

2. Pools in 2022

2.1: General Description

Reference Photographs

METHOD

Two reference photos were taken at each site: one looking downstream, and one looking upstream. The observer was positioned so that the angle and scope of the photograph matched the baseline photograph taken in 2018 (a set of photographs was taken into the field for this purpose).

RESULTS

All reference photos for each site, including looking upstream and downstream, are in Appendix. It can be discussed in two aspects: pools and vegetation.

Pools: The pools and water flow in Goodamon Creek (2022) were generally **slower** and **clearer** than 2021. There was no significant difference in visual comparison between upstream and downstream sites.

Vegetation: Vegetation on mudflats, benches, and the hillside beside Goodamon Creek in 2022 was **less** dense than last year. However, a visual comparison of reference photographs did not reveal any significant differences in vegetation height.

2.2: Indicators

Pool Depth

METHOD

The monitoring program used two metrics for pool depths, all measured with a metre rule in the deepest part of the pool: (1) total depth, which is the depth from firm substrate to water surface (or water depth plus sediment depth); and (2) sediment depth, which is the depth of sediment and was obtained by subtracting water depth from total depth. All measurements were made three times, in the deepest part of the pool that can be located by probing with a metal ruler and the mean of the three measurements was used. The type of substrate (rock, gravel, sand, silt, unconsolidated clay) was noted for each measurement, based on probing with the metal rule.

RESULTS

Total Depth (pools): The average of total depth of the pools was measured at 78.2 cm (SD = 64.5). This represents an increase compared to the previous two years that the depths were 53.1 cm (SD = 30.0) in 2021 and 67.1 cm (SD = 22.7) in 2020 (Figure 3). A high variability in total depth was observed between different sites, with depth ranging from 34.0 cm (E32) to 200 cm (E13) (Figure 3). Similar to the previous years, the deepest pools were found at E07 (82.3 cm), E09 (176.7 cm), and E13 (200 cm) (Figure 3). It should be noted that the depth at E13 was too deep to accurately measure, but it can be estimated to be 200 cm.

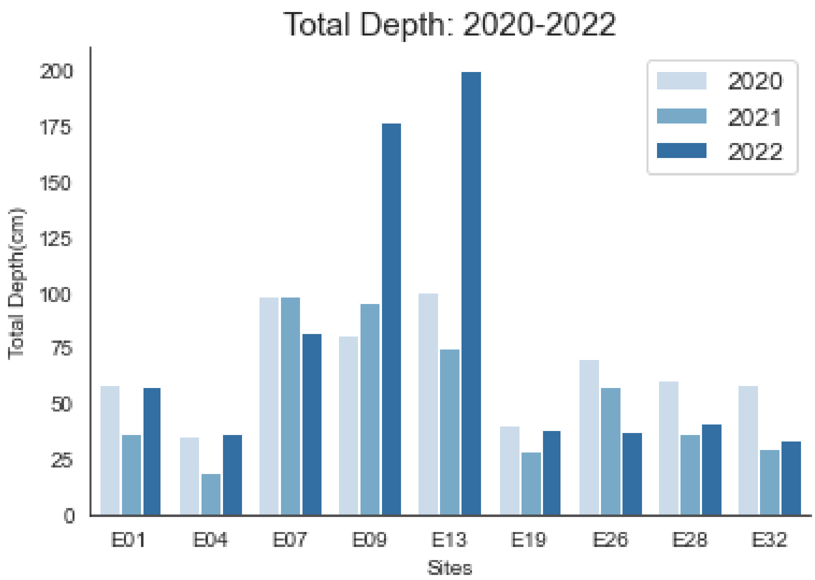


Figure 3. Total depth (Pools) along Goodamon Creek in 2020, 2021, and 2022.

Despite the overall rainfall in 2022 being lower than the previous year (Figure 2), the impact of a significant rainfall event on the 4th of August and above average rainfall in October was evident in the depth of many pools along the Corridor, particularly in sites E09 and E13. This suggests that the intensity of short-term precipitation events may play a more crucial role in determining the depth of pools, compared to the total amount of rainfall received.

Sediment Depth (pools): The depth of unconsolidated sediment was found to be 8.7 cm in average (SD = 5.1). This represents a decrease compared to the last year that the depth was measured at 10.5 cm (SD = 12.2), but an increase compared to the survey in 2020, which recorded a depth of 3.8 cm (SD = 4.8) (Figure 4). The data revealed that some sites, such as E13 and E19, had sediment depths that were barely visible (less than 4 cm). However, there were also indications of an increase in sediment depth in certain sites compared to 2021, such as E04, E07, E09, and E28. The analysis of all history data suggests that the sediment was more likely to accumulate in the most upstream site (E01) and the most downstream sites (E26, E28, and E32) (Figure 4).

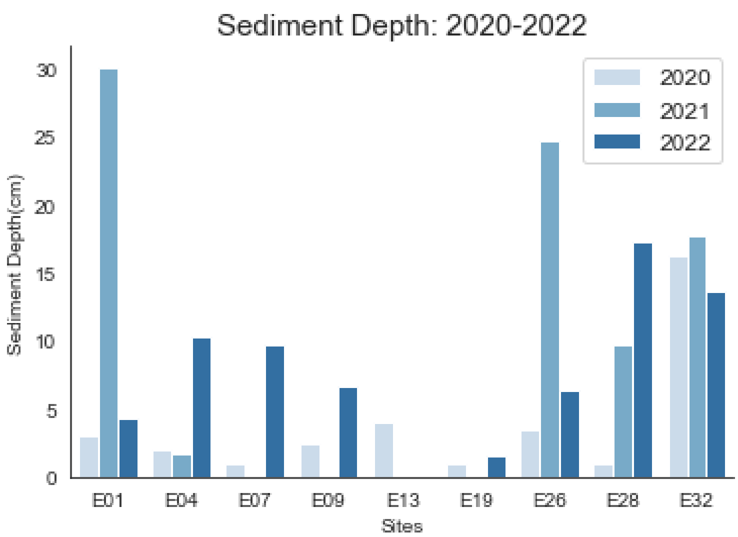


Figure 4. Sediment depth (Pools) along Goodamon Creek in 2020, 2021, and 2022

The above average rainfall in 2022 had a noticeable impact on Goodamon Creek, causing erosion and potentially affecting the sediment depth of various sites, particularly upstream areas. Additionally, the construction activity on Macnamara may have contributed to the deeper sediment depth in the upstream area as well. The inflow of water released from a dam (upstream area) into E28 and E32 may also have played an important role. To further analyze the impact of these factors, more comprehensive data collection is necessary.

Tall Emergent and Submerged Macrophytes

METHOD

Three tall emergent macrophytes and three submerged macrophytes species are used as ecological indicators: *Phragmites australis*, *Schoenoplectus tabernaemontani*, *Typha domingensis, Chara australis*, *Nitella pseudoflabellata*, and *Potamogeton crispus*. In this report, they will be referred to as *Phragmites, Schoenoplectus, Typha*, *Chara, Nitella,* and *Potamogeton* respectively.

Two metrics were used: abundance and occurrence. **Abundance**, as area of each species in the marked-out pool, was measured in the field, by treating each species as one or more simple geometric shapes (rectangle, circle, ellipse, equilateral triangle) and measuring its critical dimensions (width, length, or diameter) as relevant (assume each shape had full coverage). The total area (m^2) of emergent and submerged macrophytes species were calculated separately. **Occurrence**, meaning the number of pools where a species is recorded, is derived from area data. Additionally, the height of tall emergent macrophytes in each site and its average were measured and calculated (started from 2021), as the macrophytes are recognised as an important indication of stream health and therefore monitoring their growth has become necessary.

RESULTS

Figure 5. *Schoenoplectus tabernaemontani* (top left); *Phragmites australis* (top right); and *Typha domingensis* (bottom) in Goodamon Creek.

1. Tall Emergent Macrophytes

All three species of tall emergent macrophytes were present in Goodamon Creek in the 2022 survey (Figure 5), and no additional species were recorded.

Combined area: The area of tall emergent macrophytes was significantly lower than the previous year. The average area was found to be 7.2 m^2 (SD = 10) in 2022, which was significantly lower than the 38.4 m^2 (SD = 36.17) recorded in 2021, but higher than the 3.95 m^2 (SD = 3.88) recorded in 2020. Like previous years, the area of tall emergent macrophytes varied greatly between sites, ranging from 0.3 m^2 (E07) to 30.6 m^2 (E19) (Figure 6). Individually, there were also significant changes in the area of tall emergent macrophytes between these two years; all pools showed decreases compared to the last year. Among them, E09 had the largest decrease, with its area of tall emergent macrophytes decreasing from 128.4 m^2 in 2021 to 16.3 m^2 in 2022 (Figure 6).

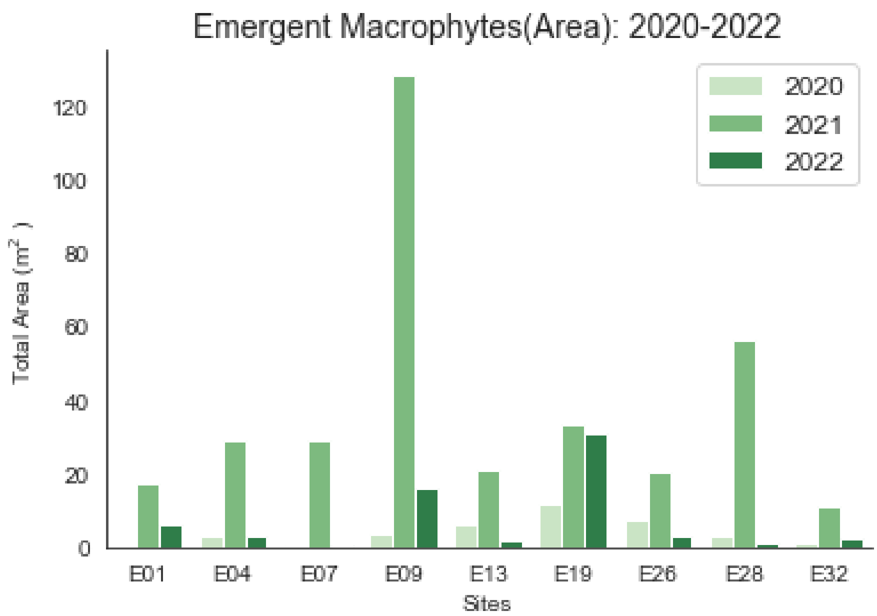


Figure 6. Area (m^2) of emergent macrophytes per pool in 2020, 2021, and 2022

Average height: The average height for tall emergent macrophytes during the spring of 2022 was found to be generally consistent with the last year. The average height measured in 2022 was 134.4 cm, while it was 135.7 cm in 2021, with no significant change observed (Figure 7). Tall emergent macrophytes in sites E13 and E19 continued to exhibit the highest average height, both measuring at 200 cm (Figure 7). Notably, the tall emergent macrophytes found in downstream sites E26 and E32 tended to have a lower average height of 63.8 cm and 36.7 cm respectively (Figure 7). The data indicates that, despite a noticeable decrease in the area of tall emergent macrophytes in 2022, the average height of the tall emergent macrophytes remained unchanged in general (Figure 6; Figure 7).

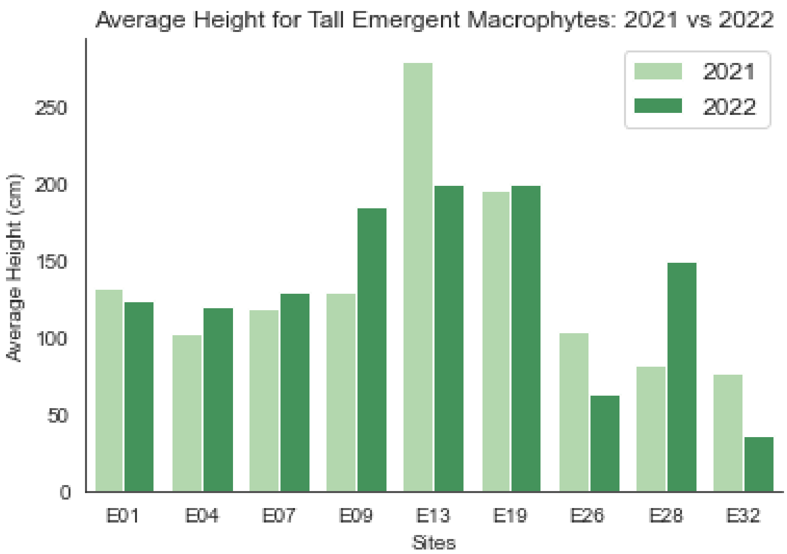


Figure 7. Average height (cm) of tall emergent macrophytes in each pool (2021 vs 2022)

Individual species: The mean area of tall emergent macrophytes in 2022 was significantly smaller compared to the last year. For example, *Phragmites* shrank from 22.60 m^2 in 2021 to 4.87 m^2 in 2022; *Schoenoplectus* decreased from 12.65 m^2 (2021) to 1.62 m^2 (2022); and *Typha* reduced from 3.15 m^2(2021) to 0.72 m^2(2022) (Table 1). Additionally, the occurrence of each species also decreased, with *Phragmites* present at 4 sites, *Schoenoplectus* at 5 sites, and *Typha* at 3 sites, compared with 8, 7, and 5 sites respectively in 2021 (Table 1).

Table 1. Mean area and occurrence for tall emergent macrophytes in 2020, 2021, 2022

	Year	*Phragmites*	*Schoenoplectus*	*Typha*
Species Area Mean (m^2) (SD) per site	2022	4.87(10.18)	1.62(2.28)	0.72(1.09)
	2021	22.60 (34.46)	12.65 (15.69)	3.15 (6.82)
	2020	2.48 (3.93)	0.41 (0.76)	0.8 (2.01)
Number of sites present	2022	4	5	3
	2021	8	7	5
	2020	5	6	4

2. Submerged Macrophytes

No indicator species of submerged macrophytes was present in Goodamon Creek in 2022, only little individuals (*Potamogeton*) were potentially seen (the population was too small to measure) in E28 (Figure 8).

Figure 8. *Potamogeton crispus* in Goodamon Creek

Combined area and occurrence: The area of submerged macrophytes and their occurrence in 2022 can be considered as none (Figure 9) (Table 2). Submerged macrophytes used to inhabit in the most downstream sites (E26, E28, and E32) (Figure 9), but not in 2022's survey. The potential reasons for the absence of submerged macrophytes could be:

1. On the 4th of August 2022, a major rain event resulted in flooding and above average flows in all waterways in the Conservation Corridor.

2. The event on the 4th of August 2022 also resulted in major erosion all along Goodamon Creek and resulted in a giant slump that continued to erode the creek (Figure 10).

3. The downstream sites of the creek were impacted by increased physical damage from both cattle and deer activities in 2022 (Table 3).

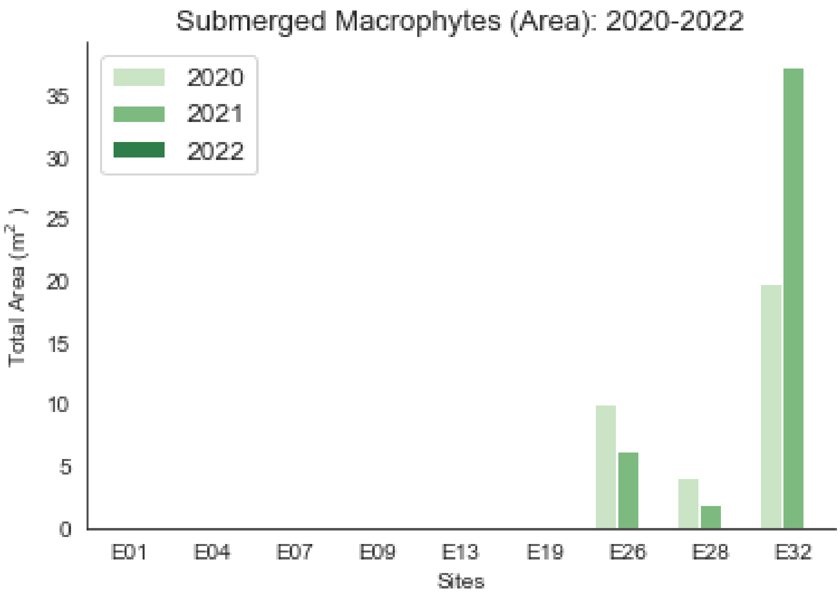


Figure 9. Area (m^2) of submerged macrophyte per pool in 2020, 2021, and 2022

Table 2. Mean area and occurrence for all submerged macrophytes in 2020, 2021, 2022

	Year	*Chara*	*Nitella*	*Potamogeton*
Species Area Mean (m^2) (SD) per site	2022	0	0	0
	2021	0	0	5.09 (12.33)
	2020	0	0	3.31(6.45)
Number of sites present	2022	0	0	0
	2021	0	0	3
	2020	0	0	3

Figure 10. A giant slump above Goodamon Creek occurred in August 2022 (just below site E13)

3. Benches in 2022

3.1: General Description

Bench condition

METHOD

Extent and severity of grazing and of physical damage (such as pugging, slumping and erosion) to soil surface or bank are noted at each site, and subsequently categorised as **none, little, some,** or **lots**. Each site was then positioned on the impact gradient, colour-coded from light (= none) to dark (= lots). The impact gradient used here was an updated version of the impact gradient used and presented in the last year's report (Roberts and Sharp, 2020).

RESULTS

The results indicated that the effects of grazing and pugging on the benches were heterogeneous, with different sites showing varying levels of impact (Table 3). Overall, the bench conditions were more severe compared to previous years of 2021 and 2020, with several sites located closer to the higher end of the impact gradient (Table 3).

Some sites, such as E07, E19, E28, and E32, where pugging, grazing or both were only causing minor impacts on them in 2021, showing significant signs of degradation in 2022 (Table 3). This was due to a combination of factors, including the increased frequency of physical damage from cattle and deer and the major erosion caused by heavy rainfall in August 2022. Only two sites (E04 and E13) had improved slightly compared with previous two years, which may indicate that the livestock changed their preferred place from E04 (2021) to the downstream sites. To recover the bench condition along Goodamon Creek, it is crucial to address the issue of grazing and pugging, particularly in the downstream sites.

Table 3. Bench condition arranged as an impact gradient

Grazing	none	none	little	little	some	some	some	little	lots
Pugging	none	little	little	some	none	little	some	lots	lots
2022			E26, E13, E09, E04		E01		E19, E07		E32, E28
2021		E09	E01, E07, E19, E26	E13, E28, E32		E04			
2020	E26, E28	E19, E32	E01, E07, E13					E04, E09	

3.2: Indicators

Bench vegetation height

METHOD

Vegetation on the bench was checked to record if it is a grassland (dominated by grasses), sedgeland, rushland or forbland. Vegetation height was estimated as an average of erect culms.

RESULTS

All benches primarily consisted of grasses, with the average height ranging from 30 cm (E04) to 170 cm (E09). This was taller than previously recorded data in 2021 (25-100 cm tall) and 2020 (15-30 cm tall). Notably, two sites (E09 and E13) recorded the highest measurements (170 cm and 165 cm tall respectively) in 2022. This likely resulted from the relatively minor impacts from animals (Table 3), soil erosion (Figure 10), and the construction on these two sites.

One woody species, Blackberry (*Rubus anglocandicans)*, was identified as a dominant species in the bench quadrat of E13 and E32 (Table 4), however other woody species such as Wattle (*Acacia)*, Hawthorn (*Crataegus monogyna*) and Sweet Briar (*Rosa rubiginosa)*, were not recorded as bench dominants in 2022.

Dominant species

METHOD

The species that dominate (that are visually most abundant) in the bench quadrat were recorded. Dominant means up to five species per quadrat, as suits.

RESULTS

An increase in the diversity of dominant species was observed, with 20 dominant species identified, surpassing the number recorded in 2021 (17 species) and 2020 (14 species). Out of these 20 species, a significant proportion of 14 species were non-native, and the most frequently recorded species were *Holcus lanatus* (7 sites; non-native) and *Avena* (4 sites; non-native) (Table 4). However, it is noteworthy that 5 new native species were documented in 2022, including *Briza minor, Themeda triandra, Austrostipa scabra, Cyperus eragrostis, Schoenus apogon* (Table 4). This may indicate a potentially positive shift towards the natural vegetation composition in the area.

Table 4. Dominant species on benches in 2022 (new species are marked with green)

Dominant Species	Occurrence in 2022	Occurrence in 2021	Occurrence in 2020	Origin
Avena barbata	4	7		Non-native
Briza minor	2			Native
Bromus hordeaceus	3	2	2	Non-native
Carthamus lanatus			1	Non-native
Cardamine hirsuta		1		Non-native
Cenchrus clandestinus		3	7	Non-native
Cynodon spp.		1		Non-native
Cynodon dactylon	3	3		Non-native
Eragrostis curvula	3	2		Non-native
Holcus lanatus	7	9	3	Non-native
Juncus articulatus		4		Non-native
Lolium spp.	1	4	4	Non-native
Paspalum distichum			1	Non-native
Phragmites spp.		1		Native
Plantago spp.		1		Non-native
Nasturtium officinale			1	Non-native
Schoenoplectus spp.	1	4		Native
Themeda triandra			1	Native
Trifolium arvense			1	Non-native
Trifolium campestre			1	Non-native
Trifolium dubium		1		Non-native
Trifolium repens	3		2	Non-native
Trifolium subterraneum			1	Non-native
Typha domingensis		1		Native
Veronica anagallis-aquatica		1	1	Non-native
Vulpia spp.	1	1	1	Non-native
Hypochaeris spp.	1			Non-native
Themeda triandra	1			Native
Conyza bonariensis	1			Non-native

Rubus anglocandicans	2			Non-native
Hypericum perforatum	2			Non-native
Austrostipa scabra	1			Native
Rumex crispus	2			Non-native
Plantago lanceolata	2			Non-native
Schoenus apogon	2			Native
Cyperus eragrostis	1			Native
Number of Dominants	20	17	14	

Quadrat Cover

METHOD

Percentage cover of bare ground (unvegetated soil with no plants growing), rocks, litter (dead material not attached to a plant), shrubs, perennials, and annuals was recorded in each 5(m) x 1(m) bench quadrat. Quadrats were set out to correspond to their position in previous years by using photographs as a guide.

RESULTS

Bare ground: The bare ground coverage at E04 experienced a noticeable improvement from 35% in 2021 (Tsai, 2022) to 16.6% in 2022 (Table 5). This is likely due to the shift of grazing activities from E04 to more downstream areas, leading to a decrease in pugging, grazing, and erosion impacts. On the other hand, the increased presence of animals at the downstream sites, such as E28, resulted in a significant increase in bare ground coverage from 0.5% in 2021 (Tsai, 2022) to 16.66% in 2022 (Table 5).

Rocks and litter: The rock cover across all benches was limited except for E01, which had a higher coverage of 23% (Table 5). This deviation could be attributed to the ongoing construction at that site. Similarly, the litter cover was low across all benches, with the exception of E13 that had a higher-than-average litter coverage (Table 5).

Shrubs: The presence of shrubs on the benches was minimal, with only two exceptions, E13 and E32, where a dominant species of blackberry (*Rubus anglocandicans*) was observed (Table 5).

Perennials and annuals: The distribution of perennials and annuals along all benches showed a noticeable trend. Perennials were observed to thrive in downstream sites, such as E26, E28, and E32, with a coverage of 59.28%, 41.66%, and 79% respectively (Table 5). Conversely, upstream sites had a higher prevalence of annuals, ranging from 61.6% (E01 and E13) to 72.8% (E09) (Table 5). These patterns in vegetation distribution may reflect differences in environmental conditions between upstream and downstream sites, such as the availability of water, soils, and animal activities.

Table 5. Cover (%) in the 5 x 1 m quadrat for each bench in 2022

	Bare Ground	Rocks	Litter	Shrubs	Perennials	Annuals
E01	3.85	23	3.85	0	7.7	61.6
E04	16.6	4.17	4.17	0	8.34	66.72
E07	9	0	4	0	19	68
E09	0	0	9.1	0	18.2	72.8
E13	0	0	23	7.7	7.7	61.6
E19	7	0	5	0	19	69
E26	0	29.6	3.71	0	59.28	7.41
E28	16.66	4.17	4.17	0	41.66	33.34
E32	4	0	4	4	79	9

4. Conclusion

For the pools, despite the weather report in 2022 not indicating a significant increase in rainfall, the total depth in each pool was generally deeper than the previous two years. This could be attributed to the significant rainfall event on the 4th of August 2022 and above average rainfall in October. However, the depth of unconsolidated sediment in 2022 was slightly shallower on average than last year, with sediment tending to accumulate in the most upstream and downstream sites. On the other hand, the area of tall emergent macrophytes in 2022 was significantly lower than the previous survey (2021) and no submerged macrophytes species were found in Goodamon Creek during the 2022's survey. It is possible that this decrease could be due to the effects of rainfall, erosion, and livestock activities in downstream sites (especially for submerged macrophytes). As observed last year, tall emergent macrophytes in three sites (E09, E13, and E19) had the highest average height. The data indicates that, despite the decline in the area of tall emergent macrophytes in 2022, the average height of the tall emergent macrophytes remained generally unchanged in comparison with the last year.

For the benches, all benches were predominantly covered by grasses with a slightly higher average height in 2022 compared to the previous two years. However, the extent of grazing and pugging damage on the benches was more significant than last year, especially in the downstream sites, which may indicate a shift in livestock grazing patterns from E04 (in 2021) to these areas in 2022. For species in bench quadrats, 20 species were noted as dominant species (higher than in 2021 and 2020) and the proportion of the native species had increased (5 more native species had been found), which may indicate a potentially positive shift in the local ecology. Moreover, the quadrat cover data revealed that perennials were more prevalent in downstream sites, while annuals were more common in the upstream sites, indicating varying environmental conditions between the upstream and downstream areas.

References

Australian Government Bureau of Meteorology (2021). Australian Capital Territory in November 2021: wettest on record http://www.bom.gov.au/climate/current/month/act/archive/202111.summary.shtml

Domensino, B, 2022, 'Canberra cops heaviest August rain in decades' *Weatherzone,* 5 August, viewed 14 March 2023, <https://www.weatherzone.com.au/news/canberra-cops-heaviest-august-rain-in-decades/730896>.

Duodu, G. O., Goonetilleke, A., & Ayoko, G. A. (2017). Factors influencing organochlorine pesticides distribution in the Brisbane River Estuarine sediment, Australia. *Marine pollution bulletin, 123*(1-2), 349-356.

Gupta, H., & Chakrapani, G. J. (2005). Temporal and spatial variations in water flow and sediment load in Narmada River Basin, India: natural and man-made factors. Environmental Geology, 48(4), 579-589.

Roberts J and Sharp S (2020). Pool and bench vegetation of Stream E, Ginninderry, ACT. Monitoring results: Spring 2019. Report Number JR 40/2020, Canberra ACT 2602.

Roberts J and Sharp S (2019). Pool and bench vegetation of Stream E, Ginninderry, ACT. Baseline in Spring 2018. Report prepared for Riverview, ACT. Report Number JR 39/2020, Canberra ACT 2602.

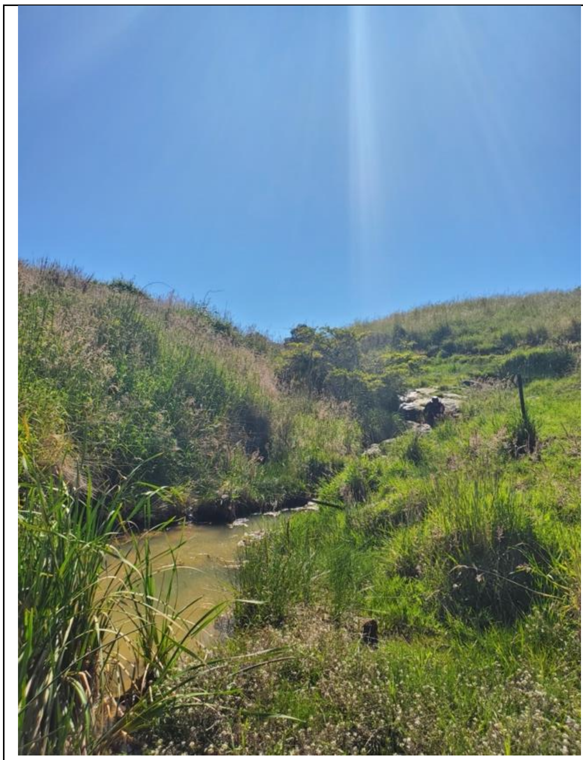
Tsai, C.-y. (2022). Pool and Bench Vegetation of Stream E, Ginninderry: spring 2021. Retrieved from https://static1.squarespace.com/static/5f3e0bee2def5c5996c055f1/t/62cf750779518c64949cfece/1657763279112/Pool+and+Bench+Vegetation+of+Stream+E%2C+Ginninderry-+++spring+2021_FINAL.pdf

Wang, B.-y., Yan, D.-c., Wen, A.-b., & Chen, J.-c. (2016). Influencing factors of sediment deposition and their spatial variability in riparian zone of the Three Gorges Reservoir, China. *Journal of Mountain Science, 13*(8), 1387-1396.

Appendix:

Reference photos of pools: 24 November 2022 vs 15-16 November 2021

Pool **E01** looking downstream: 2022 (left) vs 2021(right).



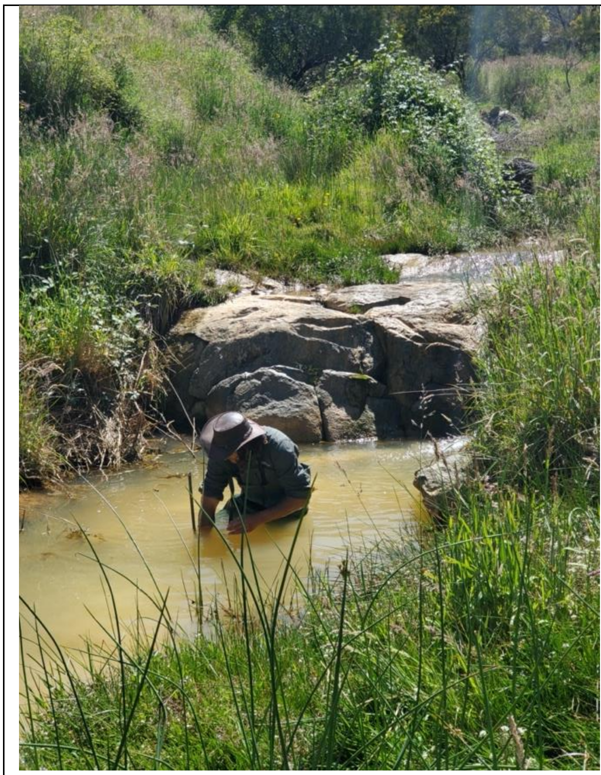
Pool **E01** looking upstream: 2022 (left) vs 2021(right).

Pool **E04** looking downstream: 2022 (left) vs 2021(right).

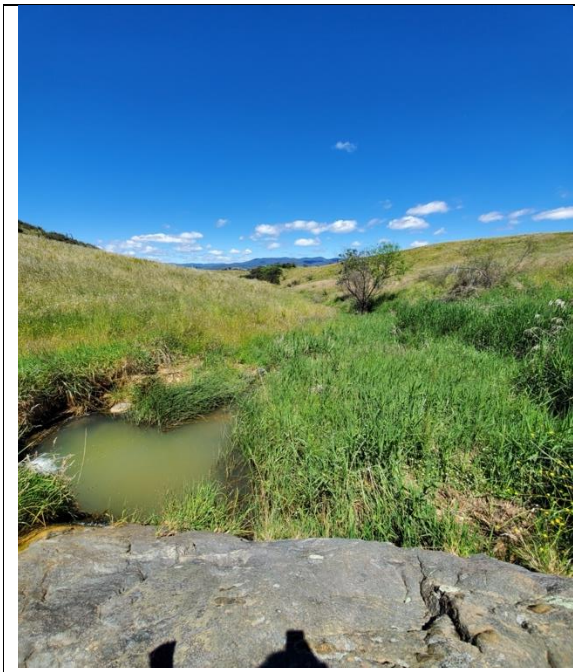
Pool **E04** looking upstream: 2022 (left) vs 2021(right).

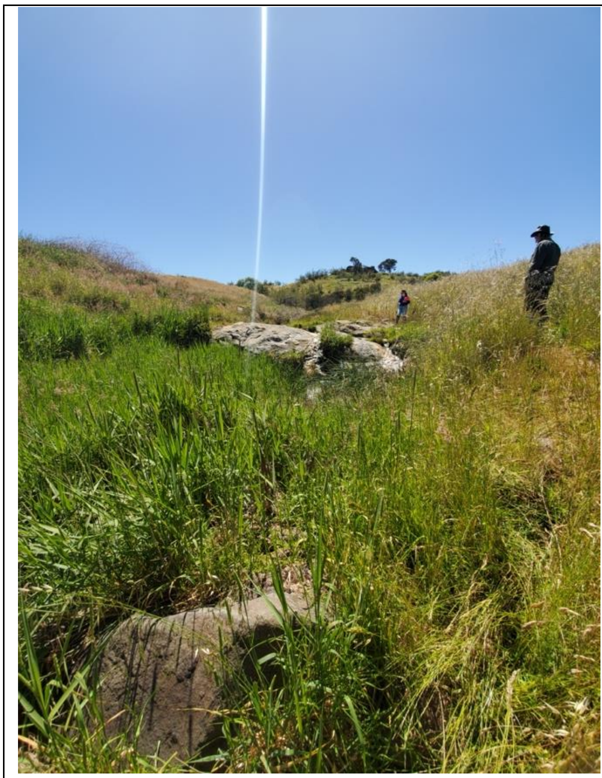
 

Pool **E07** looking downstream: 2022 (left) vs 2021(right).

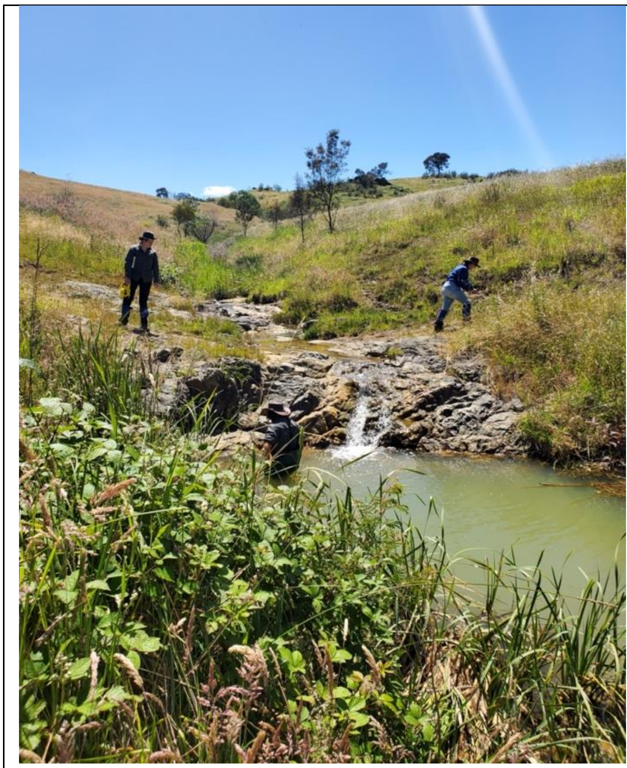
 

Pool **E07** looking upstream: 2022 (left) vs 2021(right).

	
Pool **E09** looking downstream: 2022 (left) vs 2021(right).	

	
Pool **E09** looking upstream: 2022 (left) vs 2021(right).	


Pool **E13** looking downstream: 2022 (left) vs 2021(right).



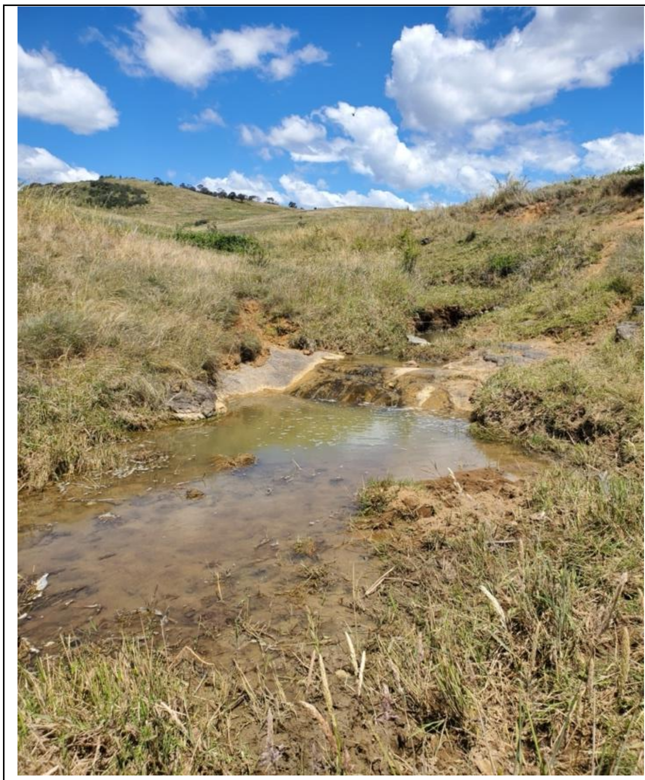

Pool **E13** looking upstream: 2022 (left) vs 2021(right).

Pool **E19** looking downstream: 2022 (left) vs 2021(right).

Pool **E19** looking upstream: 2022 (left) vs 2021(right).

Pool **E26** looking downstream: 2022 (left) vs 2021(right).

Pool **E26** looking upstream: 2022 (left) vs 2021(right).

Pool **E28** looking downstream: 2022 (left) vs 2021(right).

Pool **E28** looking upstream: 2022 (left) vs 2021(right).


Pool **E32** looking downstream: 2022 (left) vs 2021(right).


Pool **E32** looking upstream: 2022 (left) vs 2021(right).