Rehabilitation Options for
Reserve A42126
for Conservation of the
Western Swamp Tortoise.

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By

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Summary

Rehabilitation of Reserve A 42126 back to something approximating Ellen Brook Reserve will require extensive input, especially of labour, over a long period of time.

On-site water quality is good,except for high concentrations of suspended solids, which should decrease when erosion is eliminated, and the modified wetlands mature.

The Ellen Brook Reserve food web is based on a combination of unicellular alga; larger green plants, and detritus.

Phosphorus is identified as the limiting nutrient. The major source of each season's phosphorus is probably plant litter, but this needs experimental confirmation. Water column available phosphorus concentrations can be maintained low by revegetating with the native, low litter plants of the area.

The most important decisions relate to the design, location and construction of the wetlands. Within Reserve A42126 three areas of temporary wetland can be obtained with relatively limited earthworks. The need to rehabilitate portions of the existing tortoise reserve, and to integrate planning for that with the reconstruction of A42126 is pointed out. Wetland development over a three year period is recommended.

The slowest stage will be revegetation, with weed eradication a major, long term and ongoing process. Revegetation using seedlings grown from seed taken from the Ellen Brook Reserve is advocated as the best all round method of rapidly developing stable vegetation. A program for revegetation has been designed.

Tortoise could commence using the "new" wetlands as soon as the earthworks are finished and the safety fence constructed.

Public education and participation are seen as important. A rehabilitation coordinator, with reconstruction of the area as a top priority is needed. Publicity, guidance of a Friends Group, and monitoring could be supplementary tasks.

Options for further investigations and monitoring to facilitate management intervention are discussed.

Fourteen focal recommendations are made.

Recommendations

A large number of recommendations are made throughout the report. The following are central to the authors' intentions.

Wetlands

1. Design and construction of the wetlands should supply clear shallow water, grading into deeper waters.
2. Construction techniques should minimize damage to soil structure, and clearing should be followed by immediate revegetation.
3. Water capacity should be calculated only on water falling on A42126, unless water of equivalent quality becomes reliably available from other sources.

Invertebrates

4. Phosphorus concentrations should not be increased in an attempt to increase productivity, as the resultant loss of lake adaptability could be disastrous.

Earthworks

5. The locations and extent of bank constructions; fire break raising; and excavations are recommended in section 2.3 (Landforms and Soils), and Map 2 (Proposed Earthworks). The designs are for maximum depths of 1m, and water retained into December, 5 years in 6.
6. Until the new wetlands are fully constructed and vegetated, and the main drain through the south of the existing reserve dismantled, A42126 should be kept physically separated from Ellen Brook Reserve by at least a wide fire break, and its overflow water directed to Ellen Brook.

Revegetation

7. As rapidly as possible an outer "wall" of trees should be establish along the 3 exposed sides of the reserve, principally of Acacia saligna.
8. Detailed revegetation should commence from the NW corner (best remnant bush), but eradication of weeds around the wetlands, particularly the sites of proposed excavations, is also of high priority. Weed control in replanted areas should continue until the new plantings are established.
9. Before the return of tortoises, broadscale herbicide weed eradication should be undertaken on as large an area as can be rapidly replanted with native plants.
10. Once the new wetlands are stable they should be inoculated with water from Ellen Brook Reserve.

Monitoring

11. As an initial minimum, a quick and inexpensive estimate of the metabolically available phosphorus should be obtained annually by measuring filterable reactive phosphorus; total phosphorus; and chlorophyll 'a'; plus (visual) estimates of the standing crop of invertebrates and larger aquatic plants. More extensive testing should be undertaken every few years.
12. Monitoring results and feed back should be included in the "Recovery Team Annual Report", and after approval by senior management widely distributed.

Public Participation and Research

13. Public education and participation should be encouraged.
14. Basic research should be encouraged, but only permitted after careful evaluation of the habitat disturbances it will cause.

1. Introduction

The purpose of this document is to report on requirements and steps needed to develop and maintain Reserve A42126 as productive habitat for the Short Necked Tortoise (PSEUDEMYDURA UMBRINA).

Reserve A42126 ("The Site") is 5.597 ha of neglected grazing land adjacent to the SW edge of the existing Ellen Brook Tortoise Reserve. (Map reference of NW corner of A42126 6 485 870 / 408100). Rehabilitation of "The Site" for the Short Necked Tortoise will involve establishing wetlands of sufficient depth,with high production of food invertebrates; and re-establishing stable soil and stable vegetation, compatible with sustained good water quality and surrounding land use needs.

In terms of the brief for this report, this requires:-

1.1 Habitat suitable for tortoise feeding; living; reproduction; and the growth of hatchlings until late spring.

1.2 Food sources coming on stream as soon as possible.

1.3 The total area as stable as possible, given its small size, but capable of subsequently evolving towards a "natural" swamp over the coming decades.

Wetlands are not defined by the edges of the water, but by their whole catchment. The general position of a wetland in its catchment is that it is a source of water for land animals; a habitat for specialized species; and a sink for nutrients, including carbon, which slowly spiral down the slope into the water. With the exception of phosphorus and metals, they are subsequently converted to volatile compounds and recycled. Phosphorus and metals usually sediment and although they can return to the water column under appropriate chemical conditions, normally only recycle over geologic time.

Phosphorus (P), which appears to be the limiting element in the Ellen Brook Reserve and A42126 wetlands (Sect 2.2.2.2), occurs in a wide range of substances, with widely different stabilities, but only orthophosphate (PO_4^{3-}) reacts in the standard molybdenum blue test. The concentration of phosphorus in a sample is specified in terms of its method of determination: Filterable reactive phosphorus (frP) is the sum of the orthophosphate phosphorus and very easily hydrolysed phosphorus compounds, measured in a 0.45µm filtered sample. Total phosphorus (TP) is all the phosphorus in a sample, after complete digestion, (usually acid), of all 'the complex phosphorus' and sediment P. Total filterable P (TfP), also called total soluble P, is the total P in a filtered, then digested sample (= frP + soluble complex P)

Because of the uncertainty in the nature of the phosphorus species in a sample, the phosphorus quantities and concentrations are usually expressed in terms of P, not of the PO_4^{3-} that is detected. This is often designated as PO_4-P.

Since Short Necked Tortoise still survive in the existing reserve, and that habitat has co-evolved with them, a return of the site to similar conditions has the potential to provide the desired end product. But this approach may mean an expensive "locking out" of the surrounding highly modified agricultural land. Nor can there be any certainty of ultimately obtaining a quasi natural, diverse, stable, wetland habitat from former farmland.

This document analyses the available information, and presents some options for the following aspects of rehabilitating the site with respect to:-

Invertebrates :- Food sources (carbon); food web; preferred habitats.

Water :- a) quantity :- source(s); climatic variations; wet area designs for maximum invertebrate numbers, yet with enough deep water to persist until after tortoise egg laying.

b) quality :- obtain and maintain low nutrient concentrations and negligible cumulative toxic materials. Evaluate the sediment store and capacity for phosphorus and metals.

Soil :- Redeveloping structure and cover: reduce or eliminate erosion: maintain litter movement at its current level: maintain fertility.

Vegetation :- Identifying existing plant associations, and important native plant (dominant; ground; and sedge categories) and weed species; strategies for establishing and maintaining vegetative cover; and methods of (major) weed removal.

There are limited published studies of the existing reserve. Those consulted are listed in Sect. 6. References. With the exception of Water Authority water and algal analyses, the experimental data obtained specifically for this report should be replicated before being used for any other purpose. While all measurements and analyses used standard procedures (Appendix 7.1), they were only obtained for comparative purposes. In general they were neither replicated, nor their precision evaluated.

Further investigation and ongoing monitoring are recommended.

2. Present and Possible Future Conditions of the Reserves.

2.1 Invertebrates : Tortoise Food

Although all aspects of any wetland rehabilitation are linked, a primary intention of this project is an abundance of tortoise food, especially during the late spring. To provide guidance as to the most appropriately productive wetlands, we have investigated the preferred tortoise foods and the food web in the existing reserve; and have compared the number and nature of the aquatic animals in the existing reserve, with those in the newly dug, cloudy, dams on A42126.

Data on tortoise feeding is limited [1,2,3,] but it appears the adults eat any moving animal larger than about 1-2mm. During blooms they will take small Daphnia [3]. Young tortoise presumably also feed on smaller animals. Large tadpoles and fish are too large for adult tortoise [1].

Recent surveys of Ellen Brook Reserve aquatic fauna [4] are consistent with a cosmopolitan tortoise diet, as significant temporal successions of invertebrates occur during the seasons and over the years.

Factors influencing high biological productivity in temporary Coastal Plain wetlands, and the physiological and behavioural adaptation of their fauna to seasonal drying, are discussed by Balla and Davis [5]. The base of the Ellen Brook Reserve food web appears to be a combination of unicellular alga; larger green plants; and detritus (R.P. McMillan, Appendix 7.2). In addition the detritivores constitute an important component for ecosystems maintenance, because of their role in nutrient cycling.

Annual detrital biomass has not been assessed for this report because this can only be done before and during the first rains. From the number of crustacea (Isopods; Chydorids; and Ostracods) collected, detritus appears to be a significant carbon source, although these animals were also collected in association with algal fragments.

Detritus probably provides the major annual source of phosphorus.

The comparisons (Appendix 7.3) between Ellen Brook Reserve (Sites 1 and 2) and two of the wetlands constructed on "The Site" (Site 3 : Gauge No 8, and Site 4 : Gauge No 6) show the reserve exclusively containing Conchostraca, and carrying more Cladocera and Copepods, and Zygoptera later in the season, but lower in Isopods; Notonectids and Coleoptera.

There is also a general impression that the temporal succession was slower at Site 2.

These results are interpreted as the result of three effects:- cloudiness in Sites 3 and 4 limiting Cladoceran sp. and growth of rooted aquatics; also increasing water temperatures; predation at Site 2, reducing the numbers of larger invertebrates in the Reserve and combinations of depth and shade (= lower temperatures) causing Site 2 succession to be slower.

A majority of the first order consumers prefer shallow and/or clear water (Branchinella; Conchostraca; Sididae; Daphnia (excluding Simocephalus); Isopoda; Trichoptera and some Coleoptera). Design and construction of further wetlands should supply this type of habitat.

Implications for new wetland constructions are:

1. Clear shallow water will support alga; rooted aquatics; most of the invertebrates;

emergent macrophytes and Melaluca lateritia.

2. To maximize water retention these shallows need to grade into deeper waters.

3. Construction techniques should minimize damage to soil structure, (see Sect 2.2.2), and should be followed immediately by revegetation.

2.2 Water Quantity and Quality

2.2.1 Water Quantity

Water capacity should be calculated only on water falling on A42126, unless water of equivalent quality becomes reliably available from other sources.

Table 1 lists the mean monthly rainfall, over the periods 1964-1993 and 1972-1993; the monthly standard deviations(based on 1972-93 figures) an estimate of monthly evaporations, and estimates of the likely storable water during autumn and winter. The evaporation figure uses the Perth pan evaporation value [6].

To allow for climate change and annual variation the suggested volume for usable water should be the mean, less 1 standard deviation (and less evaporation). This is about 6 500 m^3. If present weather and rainfall continue, the available water can be expected to be equal to or less than this one year in every 6, or alternatively a design capacity of 6 500m^3 should fill (and usually overflow) 5 years in every 6. This frequency will also ensure the regular occurrence of at least three successive good years to enable tortoise egg laying and adequate hatchling growth before their first summer.

This is equivalent to two circular wetlands 0.6m deep, shaped like an inverted cone, and 144m diameter; or three such of 118m diameter; or four, each of 100m diameter. We suggest that in practice the shape of each wetland be determined by the natural contours, and the pool like structure resulting from the claypans be retained. This should result in adequate shoreline development, and provide a wide range of seasonally varying microhabitats, with minimum soil disturbance.

Table 1
Water supply for Tortoise Wetlands on Reserve A42126

Month	Pearce Rainfall (mm) Mean (1964-93)	Pearce Rainfall (mm) Mean (Standard Deviation) (1972-93)	Perth 1987* pan evaporation (mm)	Estimated retainable water (m^3)
April	39.2	36.4 (26.6)	110	0
May	87.8	90.9 (42.8)	72.6	850
June	146.8	131.2 (49.4)	52.2	5,300
July	138.8	135.2 (44.0)	55.6	4,600
August	107.6	109.4 (37.4)	80.4	1,500
September	67.9	64.4 (89.2)	116.6	0
Total May to August		466.7 (89.2)	260.8	11,600
			less 1 standard deviation	6,600

*Pearce median rainfall (1972 - 93) is 658.4mm. 1978 Pearce rainfall was 658.4mm.

Consideration should be given to the possibility that the gauge 6 excavation is receiving some infiltration of ground water, as its level fell more slowly than the other recent excavations, and it contained water until after 9/11/94. If there is groundwater inflow the nature of that water would need to be checked.

2.2.2 Water Quality

Appendix 7.4 summarizes water parameters measured during this season.

Three aspects need consideration:-

2.2.2.1 Turbidity.

The primary cause of the persistent water cloudiness may be an unfavourable soil Na:Ca ratio; or it may be a result of loss of soil structure, caused by loss of vegetation cover or by the earth works undertaken recently. The results of simple tests, described below, are not conclusive but suggest wind induced mixing contributes to keeping in suspension sediment derived from soil erosion, and soil characteristics contribute by causing the particles to carry a surface charge.

.The observations for this are:- The clay pit dam is still cloudy, so recency is not the only factor. However when a sample of the very cloudy Site 4 water (27/10/94 - 3.51g sediment/L) was allowed to stand undisturbed, it slowly settled, and after 2 weeks there were three layers; a thin almost clear top layer; about one third of cloudy water and the remainder looking like thin mud.

Tests on the water at Site 4 (14/9/94 - 1.04g sediment/L) found 6% of sediment larger than 1.6μm, 90% in the 1.6 - 0.45μm range, and 4% between 0.45 - 0.20μm. The final filtrate appeared only faintly opalescent (i.e. little colloidal matter present). Particles appear to carry a negative charge, and can be flocculated with small quantities of Ca^{2+} ion (approximately 1.5mg Ca^{2+} (either as $Ca(OH)_2$ or $CaSO_4$) flocculated 88mg clay over about 12 hours standing). This floc did not appear to be permanently stable since, after shaking the sediment with distilled water there was again some persistent cloudiness. High concentrations of other ions also flocculate the particles, and the water clarity in Ellen Brook Reserve may result from its more acidic water (pH 6 - 7).

Tests on surface and sub-surface air dried soil samples taken from the grass adjacent to Site 3, and the clay pan between Gauges 6 and 4, showed the surface soils (which contained roots) retained their structure and shape and did not release cloudiness when immersed in distilled water. The claypan sub-surface soil slumped rapidly, but did not produce cloudiness until shaken.

The published analysis of Ellen Brook Reserve sediment [7 : p215] records the unfavourable cation ratio of Na:Mg:Ca of 1.74 : 1.67 : 1.0.

The potential of sediment nutrients is considered in Sect 2.2.2.2., and Appendix 7.5 summarizes the chemical results obtained for the sediments.

The effects on the tortoise of the suspended particles are hard to evaluate. Based on Cladoceran numbers (14/9/94 sampling) they could reduce food invertebrates perhaps 20-50%, but chlorophyll 'a' is high, despite the shallow euphotic zone, and the high surface water temperatures. Also the 1963 descriptions of the present reserve [1] refers to cloudy water, where the water now clears relatively rapidly.

Implications for new wetlands:

1. Minimize soil disturbance and damage to soil structure (including avoidance of heavy machinery).

2. Maintain, or obtain, good vegetative ground cover.

3. If water clarification is deemed necessary, dose the wetland by dusting the surface with very fine calcium sulphate powder (gypsum). A rate of 1g $CaSO_4$ for every 25g of suspended sediment is recommended. This should maintain the pH around 7, and a single dose does not introduce enough sulphate to cause problems. An interval of some days should be allowed before assessing the effectiveness of each dose. On the evidence available this will only be temporary, and care should be exercised before repeated additions of sulphate ion: calcium carbonate, which also coagulated the sediments, (either added slowly as a carbonated suspension, or dusted on in small doses of fine powder to minimize pH changes) does not add any ion with a potential for long term accumulation or side effect.

2.2.2.2. Nutrients, including carbon.

Water Column . (Appendix 7.4)

Throughout the season the total nitrogen:total phosphorus (molar TN:TP) ratio in all of the monitored wetlands was greater than 30:1, so it is highly probable that phosphorus is limiting. The trophic status of Ellen Brook Reserve was mesotrophic in 1990 [7 : p194], and remained so in 1994. Based on TP values Sites 3 and 4 would classify as eutrophic, however as discussed below this is not their functional productivity.

The same inter-lakes study [7 :p9] also found that increases in wetland nutrients, resulted in more invertebrate animals, but with a reduction in the number of species, and in inter-annual variability in community composition. This might be interpreted as reducing the long term survival possibilities of the tortoise. The species found to increase most in eutrophic conditions were : Daphnia carinata; Candonocypris novaezelandiae (Ostracod); Micronecta robusta; Agraptocorixa hirtifrons (Hemiptera); Polypedilum nubifer and Kiefferulus interinctus (Chironamid).

For reasons discussed below it appears very probable that much of each year's aquatic nitrogen, phosphorus, and carbon comes from that seasons's vegetable litter falling on and washed into, the wetlands, ie that most of the previous year's nutrients are no longer available.

Phosphorus

In Ellen Brook Reserve water column phosphorus concentrations are relatively low, (TP = 0.04-0.05 mg L^{-1}) and much of this is mobile (frP = PO_4^{3-} = 0.02mgL^{-1}). The sediment store of P [7 : p63] is also small (ca 180μgPg^{-1}) and largely unavailable (90% iron or inert organic binding).

At Sites 3 and 4 available water column phosphorus concentrations are very similar - (frP = 0.01 - 0.05 mgL^{-1}). The high TP concentrations (0.3 mgL^{-1}) are a result of the large amount of phosphorus held on and/or in the suspended particles. This particulate P does not appear to be readily released at normal wetland temperatures, or while oxygen concentrations remain greater than 0.1mgL^{-1} [7 : p65]. However shaking the cloudy Site 4 (27/10/94) water with the strong reducing agent ascorbic acid, both causes the particles to floc, and releases significant amounts of phosphate and iron (PO_4-P rises from 0.01mgL^{-1} to 0.3mgL^{-1} and Fe from 0.07mgL^{-1} to 2.3mgL^{-1}).

On this basis the pool of phosphorus in the sediments, available while oxidizing conditions exist at the mud surface, will be small, as in Ellen Brook Reserve.

Nitrogen

At present levels, the nitrogen availability appears adequate in Ellen Brook Reserve and the new wetlands, but there are two observations, relevant to nitrogen availability.

Firstly, although there is excess nitrogen in the water (ie N : P≥ 17:1), the shallow banks of the Reserve carry large numbers of Drosera, Polpompholyx and Utricularia in a succession behind the falling water level. These are plants commonly attributed with being insectivorous because of insufficient soil nitrogen. They may grow there preferentially because of high nitrification in the soil and/or low salinity, but such profusion does not occur on the alienated lakes to the west, suggesting the nitrogen status is different here.

The second is the quite large changes in concentration of oxidized nitrogen in the water columns. In 1988 in Ellen Brook Reserve the recorded nitrate concentration is about 5 times that recorded for the previous 16 years (0.14mgL^{-1} against 0.02mgL^{-1}) and since that time it has fluctuated, but mostly been higher than prior to 1988.

The data in Appendix 7.4 shows a similar fluctuation over 2 weeks during September, so it may be a normal event, but the high levels may result from an alternative source of nitrate rich water (eg sewage, or groundwater percolation).

Carbon

While the primary producers (see section 2.4) contribute considerable fixed carbon, the litter/detritus provides an important alternative source, including CO_2. Whether this nutrient path could become excessive in the silty wetlands requires some experimental investigation, but until information is available, the litter loading should be kept low.

Implications of wetland nutrients status for rehabilitation.

1. An attempt to increase the carrying capacity of the reserve by increasing productivity by increasing phosphate concentrations may only provide a short term solution . The loss of lake adaptability resultant from higher phosphorus concentrations [7 : p10] could be disastrous in the event of major seasonal change.

2. The invertebrates favoured by eutrophy listed above, can be considered as biological indicators of the wetlands lack of health.

3. To prevent the release of sediment iron(III) bound phosphorus it will be necessary to avoid conditions that render the sediment surface reducing (O_2 concentrations $\leq$ 0.1ppm), such as deep still water; excessive fine organic detritus; blooms of alga.

4. The vegetation of the whole catchment needs to consist principally of plants with relatively low litter rates, so that the detrital loading of each wetland is relatively small. The best option will be to re-establish essentially the same vegetation as in Ellen Brook Reserve, free of annual weed species.

2.2.2.3 Toxic materials, including sub-lethal concentrations of toxic metals or persistent pesticides.

The Wetlands Classification Study [7 : p215, 216] did not detect significant concentrations of arsenic, nor organochlorine, or organophosphate residue in the Ellen Brook Reserve sediments. Although A42126 has been partly cleared for some time, there is no reason to suspect tortoise or invertebrate poisons in the wetlands sections. However sediment analyses, including sources of run-off, should be carried out.

Soils (Sediments). (Appendix 7.5)

Ellen Brook Reserve sediments contain a small store of phosphorus and carbon [7 : p215], with the phosphorus mostly in organic, and non-apatite forms [7 : p63], neither of which is readily available.

On the basis of two samples it appears that the claypans in A42126 are similarly low in available phosphorus (0.005%), but the fine,dark soil adjacent to Site 3 contains more phosphorus, though still low at 0.04%. The underlying soil contained less phosphorus, suggesting relatively recent acquisition by the surface sediments. Much of this phosphorus is bound to iron(III).

At these concentrations sediment release of phosphorus will not be a problem unless the bottom of the water becomes anaerobic ($O_2 \leq 0.1 mgL^{-1}$).

Measurement of the sediments' phosphorus uptake rates and capacities are recommended to assist in determining the assimilative capacity of each wetland, should phosphorus loadings increase.

2.3 Landforms and Soils. (8. Map 1)

2.3.1 Existing Situation.

The existing tortoise reserve has a series of inter-connected shallow wetlands with slightly deeper portions lying mostly on the gilgai clay. The vegetation largely mirrors this.

Map 1 shows the existing excavations and the contours of A42126. It originally constituted the upper portion of the natural drainage line running north west through the Ellen Brook Reserve. Planning for rehabilitation should be for the two areas together, though work on A42126 should begin first. The contours of Map 1 are matched to those plotted in the Ellen Brook Nature Reserve Surface Water Study [8] as these latter were established using surveyed reference points. The contours differ by about 1m from the air photo interpretations in DOLA map BG35/10.03W.

The most distinctive features of A42126 are:-

1. It is largely flat, with a gentle fall (of 2m) from SW to NE.

2. The largely "farm" drainage patterns imposed on the block by banks and channels.

3. The recently constructed dams with their banks of spoil.

4. The remnant shallow wetlands, and the remnant or regrowth native vegetation only partly reflecting soil and water conditions.

Less obvious are the pugging of the clay areas; the nature of the block's other soils; and the cause(s) of the high load of suspended matter in the water.

2.3.2 Construction of New Wetlands.

This is the central issue of the project, that will determine both the success, and the time scale of the program, although revegetation will probably be rate determining for recovery after wetland construction.

The results of the earth works must be stable to erosion when revegetated, in order to obtain an essentially stable wetland environment, needing no further (major) human inputs, but the reconstructed plant communities must also be stable, and the water retained support tortoises and their food until December.

Specific designs are, we suggest, the province of a civil or soil engineer, or similarly experienced person, but from the contours it appears three seasonal wetlands (marked on Map 2), can be created with relatively little disturbance to the soil of the block.

All three wetlands need some bunding in order to retain a sufficient depth of water for long enough. (The average water level falls expected from evaporation, over the months of September to December, are about 50, 90, 160, and 200 mm respectively. If any excavation consistently (more frequently than 5 years in 6), retains water in January it should be slightly filled) The order of magnitude calculations on which the bund heights were selected are summarized in Appendix 7.6.

The sequence of operations is outlined below; the notes (below and Map 2), indicate important restrictions or constraints on the operations. The start should be with the south west wetland.

The trial Gauge 7 excavation should be refilled and levelled.

By rearranging the spoil from the Gauge 6 excavation (G6) the 18.5m bank on the north side should be raised to 18.56m and linked to the west bank of the clay pit, and on, to join the existing southern bank directing water into the clay pit. The western end of this bank, and the adjacent 20 - 30mm high ridges, by the line of Acacias, should be levelled to allow free drainage into the G6 wetland. The basin enclosed by this bank will retain about 650m^3 of water, around 100mm deep. Enlarging the G6 excavation by removing the existing spoil bank, and excavating all the denuded soil into a saucer shaped depression, approximately 30m diameter, and 600mm depth below adjacent ground level (max. depth 700mm), increases the wetland's capacity to about 800m^3. Most of the claypan will dry in September or early October, and the existing vegetation can probably tolerate this duration of immersion, but in most years the G6 excavation should retain water into December.

To prevent entry of runoff from the adjacent southern paddock, the bank alongside the southern fire break needs to be made continuous, and an alternative drainage channel dug for this water - either east or west, depending on the long term drainage plans for the southern section.

At the same time the western fire break, from the south west corner, to the 18.5m contour, should be raised to at least 18.5m, to prevent loss of water when sudden storms occur.

Also the banks of the clay pit should be pushed back into that excavation at this time, until the bank height is 18.56m on the west, and ground level elsewhere. Additional clay/spoil may be needed later to reduce its depth to around 700mm, but this should be left until after all the major works are completed and the returned soil has settled, even though it may mean a temporary track through re-establishing vegetation.

Also in need of early treatment is the old dam on the east, which should be filled and levelled. The Eastern fence line needs to be marked and the boundary fire break established.

and built up to ≥18.0m, as a causeway, along the low section, to prevent flooding the adjacent (eastern) block. The overflow from the area should then follow (in reverse) the existing drainage lines, and flow north.

In the next operation an excavation down to the 17m contour should be dug in the old drainage channel, and portions of the bank along the existing track removed. (Before this is started the wetland weeds of the north eastern region need to have been eradicated.) This will impound about 1,400m^3 of water.

The final earthworks program for A42126 needs to be for the north and north west, which function as a unit. To stop loss of water to the natural drainage to the north, the whole of the low portion of the northern fire break track should be raised to 17.5m. To integrate the claypans, the spoil walls around G5 and G8 should be removed down to 17.5m, perhaps lower, and the G8 excavation could be extended further east, even as far as the 17.5m contour, if the the underlying soil's porosity is low enough. The assumption is that wetland weeds are eliminated from this region by this time. This should result in about 900m^2 of wetland still being left at the start of a "typical" December, provided soil is sufficiently impervious.

In subsequent years rehabilitation of the lower drainage region (in the Ellen Brook Reserve) should be undertaken.

NOTES

1. The resultant changes in the duration of inundation of much of the area will cause vegetation changes. This must be monitored carefully for some years, and the earthworks program implemented sufficiently slowly to allow for changes in the native plants, without too much opportunity for weed invasion. Stepped raising of the water level, with transplanting of damp habitat natives, from flooded to marginal regions, may be possible.
2. Construction of the earth works needs to be done in conjunction with the revegetation.
3. Piles of spoil, and high dam banks, are unstable structures. The constructed banks need to be broad enough to grow native vegetation on them, or carry the fire break; have sides no steeper than 30°; be well packed and rapidly revegetated. (If large areas of clay are involved, it would be advisable to have its angle of rest determined in a soil laboratory.) Consideration needs to be given to constructing tortoise aestivation chambers in a way that does not result in mounds of erodable soil.
4. To allow overflow from the south west to the north, and from the northern section into the natural drainage line, with minimum erosion, will require some form of low energy overflow area. This is probably best done using multiple overflow points, each overflow site being either embedded parallel ceramic pipes, or some form of rip-rap, in every case discharging onto a resistant base. However the tops of all banks need to be erosionally stable in case blockages in the overflows could lead to water flowing over it
5. Heavy machinery should be kept on the fire breaks while the subsoil is damp and soft. Cartage of spoil should preferably be done in smaller, light weight vehicles, not heavy trucks, or large front end loaders.
6. After construction of the eastern excavation, and later the northern bund, the aeration at the bottom of the excavations in both areas should be monitored carefully and frequently for several seasons, as maximum water depths will be around 1m, and wind mixing may be insufficient to maintain oxygen concentrations of the bottom water always >0.1mgL^{-1}. If there is any sign of Fe(III) reducing conditions in the surface sediments, eg early morning oxygen concentrations less than about 0.2mgL^{-1}, or increased frP or alga, the water level should be set lower.
7. For access to the south west wetlands for monitoring and revegetation,it may be useful to establish the top of the 18.56m bank as a pathway, not for heavy traffic: it too should be revegetated; but as the preferred track. During the high water period it will be easier to use if the bank is raised above 18.6m, but the overflow points, (at a number of spots along the bank) be set at the 18.56m level. Raising the overflow above this height will only inundate more non-clay soil to the south, and increase the flow to the east, neither of which is likely to improve the overall carrying capacity of the reserve.
8. To achieve rapid revegetation of the bunds it may be desirable to coat them with a layer of imported, (pathogen free), seed bearing, top soil of a similar type.

General Comment

Until the new Wetlands are fully constructed and vegetated, and the main drain through the south of the existing reserve dismantled, A42126 should be kept physically separated from Ellen Brook Reserve by at least a wide fire break, and its overflow water directed to Ellen Brook.

For security and for the convenience of operating a Friend's Group, there would be value in retaining all the existing Ellen Brook Reserve fence, and constructing a new fence around the three open sides of A42126. Two separate gates would then be needed, one from the outside (near a car parking area?) directly into A42126, for Friends, a second between A42126, (with separate lock) for those who needed to move between reserves, (See Section 4.2).

2.4 Vegetation.

2.4.1 Existing Vegetation

The vegetation of the Reserve was not surveyed, but general observations suggests the species listed in 1963 [1], (copy in Appendix 7.7), are still present.

The deeper portions of the wetlands are well shaded, mostly with Melaluca lateritia but there appear to be fewer clumps of emergent macrophytes than in 1963 (Plate 2). The soil under the shallow water carried a thick crop of Isolepsis marginata, which by the time of drying had disappeared from the formerly wet area and were replaced by small everlastings (Plate 1). In addition the shallow areas contained Triglochin procera.

The Isolepsis marginata appeared to be significant as offering habitat; grazing; photosynthetic O_2; and providing soil stability.

With 3 exceptions there appears to have been little spread of weeds in the core area of the reserve: alongside the path from the gate there is a concentration of weeds; Romulea rosea is now growing and flowering in the shallow wet areas on the N side of the wetlands, and one plant of Watsonia sp was observed on the NW edge. However away from the core more weeds are visible, and the Cape Tulip on the SW side, near the drain, will need elimination very soon.

Implications for management of the Tortoise Reserve are:-

1. Minimum bush disturbance (see Section 4.2) is needed to minimize weeds, and

2. Significant resources need to be invested in an initial weed eradication program, and a long term maintenance program established.

Map 3 shows the major vegetation associations observed on Reserve A42126 over September and October 1994. It is important to monitor, and record, the weeds of the reserve over the whole twelve months, as weed successions can occur rapidly. Plates 1 - 6 (Section 8) illustrate the conditions during spring 1994.

The dominant vegetation on most of A42126 is regrowth Acacia saligna, intermixed in the NW region with some other native plants (Plates 3 and 4), and an open belt of exotic weeds along the south (Plate 6). Despite the high density of understorey weeds, there are a number of clumps of Dampeia ?coronata (more obvious in late spring when its green leaves stand out against the brown weeds), one clump of Hibbertia hypericoides. There are still 3 relatively open remnants of shallow inundation areas within the reserve (Plate 5), carrying some appropriate native shrubs and herbs.

In the excavated wetlands there were rooted plants only at Site 3 (Gauge 8) and these were close to the edge, the shallow euphotic zone in all the dams inhibiting deeper plants. However the clay pit carried some filamentous alga floating near the edges, and Sites 3 and 4 (Gauge 6) yielded comparatively high chlorophyll 'a' concentrations. Because of the opacity of the water the algologist was unable to count algal cells in Site 4 samples.

2.4.2 Revegetation and Weed Control

The task is one of bush reconstruction rather than just repair, and could take decades to complete. In this document we outline the strategy, major tasks and their priorities, (also see

Appendix 7.8), but the revegetation team leader(s) will need to regularly evaluate, and allocate, the resources available for the tasks, in the light of developments on the ground.

2.4.2.1 Principles

The basic principles of bush regeneration are now well established [eg 9,10,11]. In summary the main points are:-

1. Revegetation takes time. (Even to grow Acacia saligna to 3m takes around 5 years.)
2. Rehabilitation is best started from the least damaged bush area, with a secure boundary behind to avoid reintroduction of weeds, but must also include an area or areas where progress is clearly visible to casual observers, as well as the revegetators.
3. The process can only proceed as fast as the reconstructed bush recovers.
4. The planner must know the weeds and their weaknesses. (See Appendix 7.9.)
5. At A42126 the changes in water regime will provide new weed opportunities, as well as influencing the remnant native plants. The presence of both dry and wet habitats, and several soil types also complicates weed control. Only regular monitoring will identify problems.
6. Weed infestations are dynamic: many weeds are opportunistic. Invasions of 'new' weeds must be watched for, and dealt with before getting out of control. (eg Bridal creeper can appear suddenly as it is transferred by birds.)
7. Eradicated weeds must be replaced by another plant. There may be times when the replacement is another , more easily eradicated weed (eg replacing Oxalis spp. by a 'Fusilade' sensitive grass).
8. Small pockets of new or invasive weeds should be eradicated quickly, before they spread. (eg The Watsonias in both reserves, and adjacent the western boundary of the existing tortoise reserve.)
9. Regular follow up on earlier work is essential. Aspects include:- monitoring; removal, or otherwise dealing with, new or residual weeds; assisting revegetation by summer watering of seedlings(first summer only); spreading seed; control of heavy insect attacks on seedlings.
10. The plants and seeds of the local area and soils should be used.
11. Records must be kept, including photographs (and their negatives, esp. if colour film is used), in documented and accessible forms.
12. A requirement for directing the A42126 revegetation work is a team leader with that task as top priority, and adequate flexible time to devote to it.

2.4.2.2 Strategy Outline.

Specific tasks and priorities are listed in Appendix 7.8, while map 3 shows the vegetation rehabilitation zones.

To obtain a truly stable environment which supports tortoises in an isolated remnant like Ellen Brook is impossible, and weed invasion will be continuous. Maintenance will require two complementary programs. Firstly the continuous removal of all exotics with potential to spread or be pests in the surrounding land, which initially means all introduced plants, Secondly a planting program of natives of the region and soil. This should:-

* minimize re-entry of exotics
* maintain soil structure and soil stability
* control litter, hence nutrient, movement into the water
* reduce fire risk (principally by reducing seasonal grasses)
* eliminate the risk of toxic materials leaching from exotics.

The recommended strategy applies a replanting (seedling), approach, introducing major plants first, gradually revegetating with other species, and supplementing with seeding. Seedlings are favoured for speed, and because of the difficulty of getting seeds to grow on clay. This "condensed succession" is less wasteful of plants, shows steady improvements over time, and offers more flexibility for the reserve manager.

The particular plantings, ie species and spacings, need the advice of native plant gardeners and local naturalists who know the flora and soils of the region. A starting point should be the species listed in Appendix 7.7 (Reference 1) and their natural distribution in the Ellen Brook Reserve.

1. As rapidly as possible establish an outer "wall" (say 10m wide) along the 3 exposed

sides, principally of Acacia saligna, also Hakea prostrata, Viminaria juncea, and adjacent to wet areas, Eucalyptus rudis, and understorey shrubs (Hypocalymma angustifolium), since the wall of vegetation around Ellen Brook Reserve appears to help maintain it relatively free of wind blown weeds.

Immediately inside this boundary, another 10 - 20m should be planted with Eucalyptus calophylla (drier sections) and the appropriate taller plants found in Ellen Brook Reserve [1], (Appendix 7.7). The inner portions of the reserve should be planted with appropriate plants as soon as the weeds are under control.

2. Commence detailed revegetation from the NW corner (Zone 1: best remnant bush), but continue eradication around the wetlands and in the replanted areas until their new plants are established.

3. Before the return of tortoises, do as much broadscale herbicide weed eradication as can be rapidly replanted with rapidly established native plants. Obvious sections are Zone 6; weed infested parts of the east; and around the wetlands (but see Appendix 7.9 for cautions).

4. Concurrent with work on Zone 1 a start must be made on wetland weed eradication around the proposed site of the eastern excavation and the existing G8 region. Once they are are free of weeds and replanted (with Isolepsis marginata, and everlastings), they should be used as secondary centres from which to spread revegetation. Especially start replanting Melaluca lateritia on the clay pans.

5. Once the new wetlands are stable they should be inoculated with water from Ellen Brook Reserve. For at least one year, perhaps every two months, including late in the season, 1 bucket of water should be poured into each new wetland. (To ensure transfer of bacteria/microorganisms; alga and seeds (especially of Hydrocotyl lemnoides) to the wetlands).

6. It may also be valuable to transfer in late summer, small amounts of the seed bearing, dried top mud from areas of Ellen Brook Reserve and A42126 where, in the past, receding water was followed by a succession of native plants, and put it where the newly created temporary immersion occurs.

7. A condition of entry to the reserve should that in moving about and working there be minimum disturbance.

8. Once the extent of resources; the effects of earthworks; and a full year's observation of the weeds are available, a detailed weed control plan should be developed (and written down), in collaboration with the Friends, CALM biologists, and local naturalists, eg Darling Range, or Northern Suburbs, Branches of the Wildflower Society of Western Australia or the Darling Range, or Waneroo & Northern Suburbs, Branches of the Western Australian Naturalists' Club.

Detailed sequences are given in Appendix 7.8.

3. Public Participation and Public Relations.

3.1 Public education and participation should be encouraged.

We have noted considerable public interested in both conservation of Short Neck Tortoises and how it is being done. However our impression is that most people do not appreciate the difficulties of creating an appropriate, diverse, stable habitat which will function with only solar energy inputs (ie with no maintenance), and much education is needed.

3.2. Five public relations techniques worth considering are:-

3.2.1 Use of Media

Effective and controlled use of the media to generate positive and controlled publicity is recommended. To minimize disruption of researchers, a specialist media officer is desirable. The coordinator of the Friends' Group may be able to assist with preparation and dissemination of some articles.

3.2.2 Establish a Friends' Group

To be successful this will need a vigorous leader : really needs to be someone at least part time on CALM pay roll, with time and office resources. Needs to be informed environmentally and a good record keeper, but also a good coordinator of tasks and people.

Members need to have opportunity to make comment and suggestions which will be honestly considered and discussed by the decision makers. They also need occasional, but regular briefings by scientists working on the project, and feed back on the strategy and its progress.

Some characteristics of most Friends' Groups are:-

The group only moves slowly.

Membership changes over time, and some members are infrequent participants (but no less "valuable").

Many members need, and seek advice on topics such as weeding techniques; what are weeds and which are native plants, particularly with regard to grasses; use of fertilizers.

The Group leader needs to tactfully keep workers dealing with specific tasks, such as eradicating only one specified weed, and to watch for the enthusiastic helper who is unintentionally doing more harm than good. This includes those who believe they already know a particular technique, eg planting out, but in fact don't do it sufficiently well.

3.2.3 Construct a Viewing Platform

Construct a 1m high, slatted floor, slatted roof, low maintenance, viewing platform, with limited key information, adjacent to "off highway" parking. (In no way habitable).

Needs to be beyond stones throw of the fence, and on the far side of the fire break and the drainage ditch. Large signs to point to nearest toilets (at? -but not on site).

Information:- key information about tortoise life habits, and reproduction (must include pictures and diagrams).

Basic description of habitat, and outlines of habitat rehabilitation program. Phone Nos or other contact for eg Office and/or friends group.

3.2.4 Prepare an Informative Booklet

Produce a small, (quality but inexpensive!) book/booklet, for sale(distribution?) at centres of interest (Tourist Bureau; King Park; CALM; Freemantle Arts Centre; the local wineries, craft centres, garages; and etc)(A large example is "Moondyne Nature Reserve; A Guide." Gillian Crook(1994). (W.A. Dept of Fisheries and Wildlife, Perth. [12])

3.2.5 Increasing public awareness, and developing favourable attitudes, especially of children, through educational merchandising. NB Market research is needed first, and the mechanism might be through a licensing arrangement.

eg Production and sale (in the same outlets as for the publication) of:-

Tortoise T-shirts; windcheaters; tea towels.

Crafted wooden or ceramic model tortoise, or scale model moulded plastic tortoise replicas (but not both).

Wall charts; photographs; and postcards (tortoise; its food; and its habitat).

4. Future Monitoring and Research.

4.1 While monitoring will, and should[13], contribute insight into community processes[14], the purpose here is to outline practical pathways to use the monitoring data for preemptive management. We see two aspects to this: the chain of information flow; and the collection of that information.

Experience suggests the processes of monitoring and their application need a trigger, and a specified action date. We therefore recommend that an evaluation of the calender year's activities and monitoring, together with any desired changes in the next year, be included in the "Recovery Team Annual Report". After approval by senior management this information should be included in appropriate, widely distributed, publications.

The design of a monitoring program requires a model of the dynamics and nutrient cycles in the reserve, including climatic effects. On this point the approximately 7 year cycles in Perth weather should be considered as setting a minimum time for any data base.

In the absence of a quantitative tortoise nutrition model the initial chemical monitoring program is based on the following:-

1 Assume food is limiting for tortoise population size.

2 Assume the size of the metabolic pool of phosphorus is limiting on food biomass.

3 An approximation of the instantaneous metabolic phosphorus pool is the sum of:-

  i Water column reactive phosphate (ie rP, but estimated by frP).

  ii Phosphorus in the living biota (ie TP less frP and particulate P).

This latter can be estimated by measuring either TP. and particulate P. if it varies much, or measuring chlorophyll 'a', plus (visual) estimates of the standing crop of invertebrates and larger aquatic plants. This does not allow for detrital phosphorus which will be slowly released by detritivores, but for an annual sampling, it is an estimate of available P that is relatively inexpensive in time and money.

Additional monitoring measurements worth considering are:-

* Depth - can infer general temperature range, and estimate drying time.
* pH - gives considerable information described in Reference 7 (pp7). This is extended if the time of day and lighting conditions are included.
* Clarity - apart from an indication of the non-available portion of TP it also indicates wind stirring, and the potential for rooted aquatic vegetation growth.
* Colour - change in detrital breakdown could lead to water colour changes.
* Conductivity is useful [7 ; p13], and quick if the equipment is available.
* Total nitrogen (persulphate nitrogen) or even just total Kjeldahl nitrogen should be determined often enough to check that the N:P is ≥ 17.

Recommendation:

Annually, at least, measure frP; pH; and ammonia with a field kit (Appendix 7.10), and note depth and water colour; and categorize water clarity. Obtain laboratory analyses of TP and chlorophyll'a" on samples of the same water.

The above measurements would be more useful if obtained at the same time (±24 hours) as the invertebrate sampling. Suggested indicator invertebrate species are listed in Sect 2.2.2.2.

Since invertebrate numbers are seasonal, while monitoring is relatively simple, the inter-season comparisons might best be made for similar water depths each year.

The specific methods of monitoring, and selection of sites could follow one of the strategies already investigated by CALM [eg 15]. Without knowledge of the dynamics of, and in, the wetlands, it is impossible to guess at the reproducibility and representationalness of any single sampling site.

This could be reduced if every few years some sequential water sampling was undertaken. This would also provide information on processes which produce change over the time interval between measurements. For many aquatic nutrient changes, this is between about 2 hours (eg algal uptake of PO_4^{3-}) and 2 weeks (sorption of PO_4^{3-} to sediment iron). The results in Appendix 7.4 show the P and N processes were faster than 14 days on most occasions in 1994.

To explore important nutrient data in the field, some consideration should be given to using one of the field kits - such as the Hach or Palintest kits. Some information on these is given in Appendix 7.10.

Another feasible adjunct for monitoring ease would be installation of a remote (solar powered) monitoring pack with radio transmission relaying data back to base. Transducers for physical parameters are readily available. Chemical transducers usually have shorter field lives (weeks or months) but are worth investigating. (CSIRO Division of Water Resources, Canberra, have developed a relatively long life, fully immersible version.)

4.2 Research

Any consideration of research in either reserve should only be made after careful consideration of the disturbance it will cause. The most obvious are the weeds in Ellen Brook Reserve alongside the foot track from the gate, and the depression of the clay where it has been regularly walked on. As little as two walks along the same path on one wet remnant clay pan in A42126 left a track that was clearly visible after drying.

Within these constraints the following topics bear on the future of the Short Necked Tortoise:

1. Rates of nutrient (litter) fall and movement into the wetlands.
2. Future rainfall and existing water drainage paths.
3. Rates of wetland sedimentation.
4. Seasonal invertebrate successions and interdependent wetland characteristics.
5. Factors triggering changes in algal, and invertebrate species and numbers.
6. Roles of terrestrial animals and especially top consumers (eg snake, lizard, heron).
7. Detailed nutrient chemical species and their cycling in the water column.
8. The chemistry of the sediments, and especially their phosphorus retention.
9. Source and properties of the water borne suspended particles in A42126.

10. Evaluation of relevant herbicides for safe weed eradication without damage to native plants or animals.

5. Acknowledgements.

We wish to thank all those who have assisted with data, information, and advice, and specifically:- H. Gregory and G. Lantzke for assistance in the field; A. Burbidge; S. Halse and G. Kuchling for advice and information about Ellen Brook Reserve; N.Gibson for plant identifications; R. Shiel for invertebrate identifications; and K. Angel; H. Smolisky; J. Pearce; R. Jeffries; and K. McAlpine for information about soils; weeds; and herbicides.

We also gratefully acknowledge Mr. P. McMillan for the information on invertebrate ecology and the Water Authority for analysis of water samples.

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APPENDIX 7.1 Sample Sites and Methods.

Sites

Site 1: Open water portion of claypan, adjacent melaluca lateritia, in western arm of the winter inundated area.
Site 2: Adjacent to M lateritia, and the "path", just west of No. 1 depth gauge.
Site 3: South west corner of recently constructed dam, depth gauge No. 8.
Site 4: SW corner of recently constructed dam, No.6 depth gauge.

Methods

Ground contours: Automatic level and tape.

Vegetation survey: January 1994 airphoto; field ground truthing.

Invertebrate surveys: Sampled with a 1metre sweep of a 32cm diameter, 200μm mesh size net. Except on one occasion the water was shallow and the lower edge of the net was dragged through the detritus. For the one deep water sweep (Site 2 14/9/94) separate top and bottom sweeps were made and the results averaged. Volume swept was calculated using the effective area of immersion of the net. Total catches were counted.

Soil sampling: Single superficial cores were taken at Sites 1,2 and 3, and in the remnant claypan between Gauges 6 and 4, and air dried.
Dispersion tests used approximately 2cm square lumps.
Chemical analyses used ground, and mixed, samples.
Organic content from loss of weight on heating at approx 550C to constant weight.

Suspended particles: Particle size and silt load by filtration of known volumes through pre-dried and weighed filters (GF/A; 0.45 and 0.20μm), and subsequent drying (70C or air) and weighing.

Supplementary water and sediment chemical parameters:
pH: Universal indicator (± 0.5); Palintest (±0.1).
Total dissolved solids: determined gravimetrically by evaporation of known volume of 0.45μm filtered water. Dried at 105C.
frP - 0.45μm filtered; PO_4 using Palintest kit.
TP - Nitric - perchloric acid (10:1) digest; Palintest determinations of PO_4 and Fe in the supernatant of the neutralized digest, after treatment with approx 0.2g ascorbic acid. Without the ascorbic acid treatment P and Fe concentrations were low, but slowly increased over 30 - 60 minutes. The phosphorus was presumably held by iron (III) in the floc, (possibly hydrated aluminium compounds, which formed on transfer and dilution of the digests). Blanks and standards carried through the process gave acceptable values. Although the treatment used here generally gives good TP values, the iron values appear low (Appendix 7.5), possibly because of the retention of complexed iron in the floc.

APPENDIX 7.2 Invertebrate Biology

64 St Ives Northshore
Dampier Ave
Kallaroo
W.A. 6025

Dear Ian,

Herewith the information on the Ellen Brook invertebrates.

The extent of their relationship to those I collected at Guildford Grammar in the 1960's is difficult to evaluate because of the shortage of taxanomic detail in some of your categories. Within that constraint, the information about the animals I found on, and in, clayey freshwater pools and swamps (mostly around Guildford) should apply to the Ellen Brook animals.

Notwithstanding, its a pretty good collection. The Crustaceans (24 species), Coleoptera (22 species) lead with numbers, with the Crustaceans as first order consumers and the Coleoptera as 2nd order.

I recommend you consider the total food web, not just the short necked tortoise food supply. There will be other top predators also feeding on the "aquatic" web, such as heron, snakes and lizards. Rats might also play a part. There might also be natural predators of short necked tortoise, such as the Swamp Harrier.

If you could get down to their size in the swamp it would be an interesting, and terrifying place. Particularly with a short-necked swamp tortoise snapping at your heels! Roll on Steven Spielbergh!!

Cheers

P. McM.
(R.P.McMillan)

Turbellaria Your # 2
Fam: Planariidae

In swamps and temporary ponds I have collected the following - I concentrate on Guildford : These are my species observations.

Dugesia sp
Mesostoma sp
Planaria sp

Temp. Wetland, Guildford Swamp. AT the school we had a number of F.W. aquariums - the animals were observed and their behaviour noted by students and myself.

We found : All the above consumed insect remains - Small larval stages of Chironomids - They ingested a lot of detritis from aquarium bottom.

(An aside: - Mesostoma when gently squashed under cover slip and stained with Cresyl Violet showed the most beautiful chromosomes!)

Planaria sp: a black form collected from Teatree Swamp at Cannington.

Temnocephala sp - Found in great numbers on the carapace of Gilgies/Koonacs from the swamp at Guildford - Also we found the creatures on the backs of Long-necked Tortoises from the swamp. - These worms are commensals.

No reproduction observed. However the animals must produce resistant zygotes that lie in the dry mud of swamps etc.- For they appear in numbers after rain fills the swamp.

Gastropoda. (Your Nos 5 - 7 - 13 - 16
sp z sp 3 sp 4 sp 6)

Am familiar with the common F.W. snail found in ponds - At Guildford Wetland specimens were det. as Limnnaea sp. Observations in the lab. aquariums showed that they were very effective in cleaning the glass of algal growth.

Never seen in copula - The snails produced many eggs in jelly like masses attached to the substrate.

Limnaea are first order consumers.

Hydracharina - All F.W. mites are predators.
My observation *
*Cyclothrix sp
*Hydrachna sp
Your 19 ... Limnesia sp
All these are associated with F.W, or ephemeral ponds.

At Guildford in the lab. observed Hydrachna actively pursuing and eating mosquito larvae.

Cyclothrix seen to capture larval stages of Berosus sp beetle.

No reproduction observed - The animals must produce drought resistant eggs for them to appear as they do when ponds re-fill!

Consider them to be predators; 3rd Order Consumers?

BRANCHIPODIDAE (Fairy Shrimps, Daphnia, Ostracods etc)

22 Branchinella Fairy Shrimps are filter feeders consuming fine particles of organic detritus, single cell algae and small microorganisms. They are found in ephemeral swamps and rock pools and permanent F.W. lakes.

They provide drought resistant eggs/zygotes that lie in dry mud for a considerable time - Hatch out when habitat re-fills, Their normal life span is 2 to 3 weeks. Eggs could be transported in mud on legs of Herons and other birds.

They are the food for water birds and frogs. I would imagine that Short-neck Tortoises would consume lots of them!

Sexes are separate and internal fertilization. Fertile eggs remain in sac in female and may be released into the water on her death.

CLADOCERA

26 Macrothricidae - as for Daphnia re feeding and habitat.

253 Daphnia
Simocephalus Habitat F.W. lakes - Ephemeral wet lands.
Most Daphnia prefer water of less than 50cm, but found in up to 1m depth.
Daphnia prefers clearer water to Simocephalus - have collected the latter in turbid farm dams (clay).
Both these animals can appear in great numbers and are a very good food source for higher animals such as birds and frogs. They are also preyed upon by the nymphs of Dragon Flies and Damsel-flies. Dystiscidae larvae and adults. They would be an excellent food source for Short-neck Swamp Tortoise.

Daphnia can't exist in same habitat as fish - they are too quickly cleaned out!

Daphnia in the G.G.School tanks were very effective cleaners for single cell green or red algae.
(When we fed Daphnia green algae they became green and when fed red algae they became red!)

Food for both genera: single cell algae- organic particles and microorganisms - They are continual feeders.

Reproduction : Females can produce non fertilized eggs (parthenogenesis) these develop into females. One female can produce from 2 to 20 eggs. These develop in a brood chamber. There are NO free living larval stages. When wetlqnd is drying out some eggs develop into males! The females produce drought resistant eggs when swamp is drying out - these lie dormant until water returns. Sometimes after an interval of years!

Your Nos.59 - 62 - 65 - 68

CONCHOSTRACA spp
Am familiar with these two spp.

Limnadia sp Habitat F.W, ephemeral ponds/swamps.

Cyzicus sp
Food consists of small micro organisms, detritis and single cell algae.
Eaten by waders and would be very good food for small S.N. Swamp Tortoises.
I have found the animals in temp. ponds at Guildford - Armidale - Gingin and at the mine site where I work at Eneabba.

At Eneabba they appear in millions in the shallow dish like swamps - when they do the Herons and Stilts arrive in dozens to feed!

Sexes are separate - Have watched pairs in cop - they stay like this for up to an hour?s! Eggs are carried inside the female and are shed at ecdysis or death. Eggs drought resistant and can lie in dry mud for a very long time (years).
Seem to prefer shallower habitat to Daphnia, they are bottom feeders!

Ostracoda (Bean Shrimps) *? 29-33-37-40-43-46-50-53-57

Habitat : F.W. Wetlands - often in permanent water. In ephemeral habitats frequent the bottom of ponds; often can be seen moving through the bottom detritus.
Food consists of microorganisms and organic particles. are very good filter feeding cleaners.
Reproduction : Sexual and on occasions parthenogenic- eggs in temporary waterholes and swamps can lie in the dry mud for long periods. There are free living larval stages.
In habitats where algae is present and green water weed the little shrimps can be seen "browsing" among the stems and filaments. They are continually on the move.
Have seen specimens caught and eaten by Dytiscid larvae and the larval stages of Berosus sp.

In the detritus at bottom of habitats these animals are often the "commonest". They can be seen in very great numbers causing the detritus to move!! They, with the other shrimp species, could be termed "cleaners".

They are certainly a food source for the aquatic insects- would think that they might be too small for the tortoises.

Your 71-74-77-80-84-87-91

COPEPODA - I can't be much help here - I can only note their very large numbers in the Guildford swamp when it first filled with the winter rains. They were the first animals to appear apart from the Platyhelmithes and the algaes. Would be a good food source for the aquatic larval stages of Insects!

Your 94 - 99

Isopoda and Amphipoda - Detritus feeders - Have found these in the verges of Guildford Grammar School swamp in flood litter that was damp - the Amphipoda were often taken in litter/detritus in the shallow water. They were never found swimming free as in Daphnia etc! Would be excellent food for S.N.Swamp Tortoises!

Insects

Ephemeroptera. May-flies - adults don't feed.

103 Baetidae - Larval (nymphs) stages of this family are known to be detritus and algae feeders. They scrape the algae from solid surfaces. I have collected these nymphs from ponds in the coastal plain - in all cases they were crawling over "structures" such as stones, logs or eucalyptus leaves.

The nymphs are preyed upon by Dragon-fly and Damsel-fly nymphs and other larvae such as water beetles.

Some species are good indicators of a clean environment.

Odonata

Lestidae - Damsel-flies.

106 Austrolestes analis

F.W. Habitat- in permanent and Temp. Wetlands.

111 Austrolestes annulosus

Larval stages predators - they in turn are the food source of other aquatic larvae stages such as Dragon-fly nymphs and Dysticid larvae. Good food source for S.N. Swamp Tortoises!

Anisoptera - Dragon-flies - F.W. habitat - N.B. Still F.W.

114 Hemianax papneusis (is listed as Anax - is Hemianax)

One of our most common Dragon flies. As with all Dragon flies the nymphs are very good predators! They stalk and eat almost anything that moves!

Have seen them capture and eat tadpoles and quite large Gambusia! They, as well as Damsel flies and Dragon flies, lay eggs in fresh water. Female adults have an ovipositor that enables them to lay eggs in submerged tissues of aquatic plants, sometimes in decayed wood or on slime covered rocks.

Corixidae - Water-boatman

118 Micronecta robusta HABITAT; F.W. Ponds-swamps.

122 Micronecta sp

All Coroxidae predators- they feed on bottom dwelling insect larvae - at Guildford in aquariums observed feeding on Chironomidae and occasionally small Dystiscid larvae. These bugs seem to concentrate on the bottom, clinging to the substrate with hind and mid legs.

Can fly for considerable distances. Come to lights at night!

Notonectidae - Back-swimmers.

125 Anisops sp. Habitat F.W. ponds-swamps.

Predators- Have seen a Notonectid capture an adult Berosus sp water beetle.

Can fly over distances - Come to lights at night!

Both the above separate sexes.

Culicidae - Mosquitoes - Habitat F.W.

132 **Anopheles sp**

135 **Culex sp**

Chaoboridae

138 Promochlonyx australis insect Cuicidae- belongs to family chaoboridae - these insects resemble mosquitoes but don't have the long biting probiscus.

All above found in still F.W. environments - larval stages are "filter" feeders feeding on microorganisms and organic matter - both larvae and pupae are air breathers.

Sexes are separate - females lay rafts of eggs on surface of water.

Larval and pupal stages are eaten by predatory aquatic insects.

Your 142-145-148-153-156-160

I'm lumping all the Chiromidae listed.

All Chironomidae are bottom dwellers in the larval and pupal stages.

The larval stage spin loose tunnel webs of silk, and bottom detritus, forming a well defined case. They feed on organic particles filtered from the water.

Habitat : F.W.ponds and swamps.

They are the food of the larval stages of predatory insects.

As adults they emerge in millions! and are an important food source for Dragonflies and birds such as Tree Martins.

---

163 Seiomyzidae - Habitat F.W. ponds-swamps.
(Diptera)

An interesting catch- these insects in their larval stage are known to be predators on (or in!) F.W. snails.

Larvae are free living and the pupal stages float on surface of water. Could be important in control of fluke bearing snails.

Trichoptera - (Caddis-flies)

166 Hydroptilidae

Hellyethira sp Habitat ; F.W.Ponds and Swamps.

Free flying adults - sexes separate.

Eggs deposited in water. Larvae produce silk to make a web in which particles of sand and detritus are formed into a stocking or case, the larvae move around the substrate in the case, prior to pupation they attach the case to substrate.

Larval stages have chewing "jaws" - are omnivorous.

Don't know what eats them!

Are usually very common in still, clear F.W.

175 Leptoceridae Caddis fly - Habitat as above.

178 Triplectides australis

Free flyng adults - sexes separate -

Eggs deposited in water - larvae spin web and construct beautiful tubular cases with spirally arranged pieces of plant material. (Some species live in the hollow stems of water plants).

Larvae are omnivorous. (Some species are known to be predators- (on what I've no idea)).

Coleoptera

Haliplidae

183 Haliplus sp and H. Australis 143

Adult beetles are found in damp litter at edge of F.W. swamps. Often they can be found in the water at the edge. Larval stages are found in the water in plant growth in shallows. Both larvae and adults are dependent upon green algae for food.

Dytiscidae - (Water beetles!)

There are 12 species on the list:- 189-192-195-198-201-205-208-211-

216-219-222-225

I am lumping all together for my comments. With options on a few for further comment:

Both adults and larvae are predators. Their prey consists of other aquatic animals which include insects, worms, molluscs and tadpoles. (At Guildford larval stages captured and consumed tadpoles and fish, (7? Gambusia sp.)

Most larvae use mandibular channels for injecting digestive enzymes and sucking in the resulting fluids.

Both adults and larvae are air breathers.

Sexes are separate and eggs are usually deposited in slits in the stems of aquatic plants.

The adults can fly for considerable distances, are attracted to lights.

When an environment is in process of drying out the adults migrate to a more suitable environment. The insects can be found in both clear and turbid water.

Both adults and larvae would be a good food source for S.N. Tortoises.

Cybister sp. is a large water beetle- the adult can measure up to 30mm.

Copelatus sp by comparison is up to 9mm in size.

Megasporus sp. is up to 6mm

while Preoster ? sp is the smallest, 3mm in size.

---

143 Staphylinidae sp. Habitat: Damp to wet environments around edge of pools and swamps.

Usually associated with dead and decaying animal and plant remains - also associated with fungi.

Are scavanges - Can't help with this one on life cycles.

Hydrophilidae

231 sp.

234 Berosus sp. 7mm

237 sp. A

240 sp. C

243 Hydrochus sp. 3.5mm

Hydrophilidae are water beetles found in swamps - Dams ---- any place that has a semi-permanent environment!

While the adults and larvae occupy a similar type of habitat, the adults are omniverous while the larvae are predacious.

Adults are strong fliers.

Berosus sp. I've taken at Mg(mercury vapour) light miles away from any known water!

Larval stage preyed upon by other aquatic larvae and vice-versa!

---

246 Scirtidae spp. ? 8mm in size or less!
249 Scirtidae spp.

Habitat: Adults found on vegetation near water or on the ground in damp litter. Can fly.

Larvae in damp to shallow situations at edges of ponds and swamps and under litter on occasions.

Larvae are filter feeders on microorganisms and fine detritus.

Can't be much help on this last one.

Total collection:-

Platyhelminthe	1
Gastropoda	5
Crustacea	24
Ephemeroptera	1
Odonata	3
Hemiptera	3
Diptera	10
Caddis	6
Coleoptera	22

APPENDIX 7.3 Aquatic animals netted in Ellen Brook Reserve and A42126, during spring 1994.

CODE	NAME	Site3 30/8/94	Site1 14/9/94	Site2 14/9/94	Site3 14/9/94	Site4 14/9/94	S2 11/10/94	S3 11/10/94	S4 11/10/94
		No. per m3		No. per m3	No. per m3				
4200000000	TURBELLARIA	25	present (few)	13	60	270	150		
12000000000	ANNELIDA				In mud				
14110000000	HYDRACHARINA	12	present (few)	13	10			100	
14212000000	BRANCHIPODIDAE								
14230000000	CLADOCERA		present (mod)	850					
14231000000	Sididae			850 (inc ephip)			1200		
14232000000	Chydoridae	75		1000 ≥3sp(ephip)			2,500 ≥2sp		
14233000000	Macrothricidae			13					
14236000000	Daphniidae			Ceri 200(ephip)	Ceri 10	S. 80 2sp			
		S acuti 25,000		Svetulus160(ep	S acuti 50				
14240000000	OSTRACODA	6,500 4vars	12000	1,200 ≥4sp	4,000 ≥3sp	240 2sp	12,600 ≥4sp	90000	600
								most flanged sp	2sp
14250000000	CONCHOSTRACA		present(few)	40			50		
14260000000	COPEPODA								
	unclassified	88	present (few)		100	500	1400	100	
14261000000	CENTROPAGIDAE			400			≥400		80
14263000000	CYCLOPOIDAE	12000		38			250		80
14265000000	CANTHOCAMPTIDIAE								
142c0000000	ISOPODA	500		13	240	80	100	400	800
142[illegible]0000000	AMPHIPODA								
14300000000	INSECTA								
	unclassified	300							
14335000000	BAETIDAE								

APPENDIX 7.3 Aquatic animals netted in Ellen Brook Reserve and A42126, during spring 1994.

14340000000	ZYGOPTERA	200	present (few)	·25	50	54	300		
14350000000	ANISOPTERA								
1436a000000	CORIXIDAE				25	25			300 2sp
1436e00000o	NOTONECTIDAE	300	1000	present (1,000)	960	240	250	1200	620
143a0000000	DIPTERA								
	unclassified								
	mosquito	40 (?Anophal)		90	10		300		
	Chironamid			50		25			80
143ah000000	Sciomyzidae								
	(SCIOMYZIDAE)								
143d0000000	TRICHOPTERAE								
143e000000o	COLEOPTERA	24	present (mod)		110 3sp	100 2sp	200	700	1,300 ≥2sp
	TADPOLES	present	260						1 large
									& eggs
	Sample Depth	18cm	5.4cm	23.2cm	17cm	16cm	10cm	6cm	7.4cm
	Clarity	cloudy	clear	clear	low	v. low	clear	cloudy	v. cloudy
	TP (mg/L)			0.036	0.17	0.245	0.053	0.92	0.44
	frP (mg/L)					0.006			0.1
	TKN (mg/L)			0.74	3	3.1	0.97		5.2
	ToxidN (mg/L)			1.75	1.75				
	Chl'phl a(μg/L)			1.2	2.3	9.4	3.8		65
	Phaeop (μg/L)			<0.7	2.4	<1.02	<0.42		<7.3

APPENDIX 7.4 Ellen Brook Water Parameters 1994

	S2 14/9/94	S3 14/9/94	S4 14/9/94	S2 28/9/94	S3 28/9/94	S4 28/9/94	S2 11/10/94	S3 11/10/94	S4 11/10/94
Gauge depth (cm)	30	51	56			44		22	46
Sampling depth (cm	23.2	13	16.4	17	15		10	6	7.4
Temp. top (C)	16	24	23				25	26	24
Temp. bot. (C)	14	18	17				22	22	19
pH				6		7.5			
Clarity	good	poor	v.poor	good	poor	v.poor	good	poor	v.poor
TP (mg/L)	0.036	0.17	0.245	0.035	0.335	0.295	0.053	0.92	0.44
frP (mg/L)			0.006	0.022	0.045	0.015			0.01
TKN (mg/L)	0.74	3	3.1	0.76	4.8	4.4	0.97		5.2
ToxidN (mgN/L)	1.75	1.75		0.005	0.015	0.023			
TN : TP	200	78	35	64	41	42	>50		>33
Chlorophyl a (μg/L)	1.2	2.3	9.4				3.8		65
Phaeophytin (μg/L)	<0.70	2.4	<1.02				<0.42		<7.3
CHLOROPHYTA	Cosmarium 20	Chlamyd's 20	Too opaque				Sphaeroc's 100		Ankistrodesmu
(cells/mL)	Unident uni 50	Unident uni 90					unident uni 30		Scenedesmus
EUGLENAPHYTA	Euglena 10	Euglena 20	" "				Dinobryon 20		Euglena;Phacus
(cells/mL)		Trachel's 40							Trachelomonas
PYRRHOPHYTA	Peridium 40	Cryptom's 400	" "				Crypto's 70		Cryptomonas
(cells/mL)							Peridinium 30		

APPENDIX 7.4 Ellen Brook Water Parameters 1994

	Site 4 27/10/94	Claypit 27/10/94
Gauge depth (cm)	38	-
Sampling depth (cm)		
Temp top (C)		
Temp bot (C)		
pH	7.7	7.7
Clarity	opaque	poor
TfP (mg/L)	0.06	0.26
frP (mg/L)	0.02	0.01
:P (mg/L)		
Total Fe (mg/L)	110	43
Total filterable Fe (mg/L)	5	5
Total dissolved solids (mg/L)	290	-
Suspended solids (g/L)	3.5	0.3

APPENDIX 7.5 Sediment Properties.

	Site 1	Site 2	Site 3	Site 0	Ellen Brook*
Date	16/8/94	16/8/94	30/8/94	14/9/94	August 1989
TOP 2cm					
Appearance		"Rust" and clay patches; gritty.	Dark; fine texture. Roots.	Coarse; sandy. Fine roots	
TP (µg/g dw.)	60	70	380	45	100
Fe (mg/g dw.)	7	9	18	5	23
Organic matter (%)	4	4	20	3	4
Na (mg/g dw.)					1
Ca (mg/g dw.)					1
MIDDLE 3cm					
Appearance		"Rust",clay, and coarsely gritty		Coarse; sandy. 5% gravel	
TP (µg/g dw.)	75	30	100	25	
Fe (mg/g dw.)	6	10	8	3	
					* Ref 7 P215

APPENDIX 7.6 Wetland Calculations.

Calculations for the 3 proposed wetlands, using approximations, are as follows:-

Assumptions and data used.

Net rainfall (5years in 6) 197.7mm

Net evaporation (mm)	
Sept	52
Oct	87
Nov	163
Dec	206

Average coefficient of runoff (non clay soils) 0.25

Assuming no leakage from storage areas.

1 South west wetland. (Includes excavations Gauges 4,6, and 7)

Catchment areas (m^2)	Total	10,000	
	claypan	6,400	
	balance	3,600	
Available volumes of water (m^3)	claypan (precipitation)		1,200
	runoff (25% of 'remainder')		200

Using a detention level of 18.56m

Max depth of claypan 10mm

Capacity of (unexcavated) claypan $640m^3$

Additional capacity of (enlarged) G6 excavation (conical: 30m diam; 0.60m below adjacent ground) $140m^3$

<u>Max total capacity</u> <u>$800m^3$</u>

2 Eastern section

Catchment areas (m^2)	Total	11,000
	claypan	30
	rest of store area	1,800
Available water volume (m^3)	direct precipitation	500
-	direct runoff	330*

Retention level 18.0m

mean depth of storage area 0.7m

capacity of (unexcavated) storage 1,300 m^3

additional max.depth of excavation 0.30m

capacity of proposed excavation (50x10x0.3)m^3 $150m^3$

<u>Max total capacity</u> <u>1,400 m^3</u>

* There will be additional runoff from the shallower claypit dam, and the northern section.

3. Northern section, excluding its western end.

Catchment areas (m^2)	total	10,000
	retention area	6,000

Available water (m^3) 1,100 m^3

Retention level 17.5m

Capacity of (unexcavated) retention area 340 m^3

Additional capacity of G5 300 m^3

Additional capacity of existing G8 20 m^3

<u>Max total capacity</u> <u>700 m^3</u>

APPENDIX 7.7 1963 List of Ellen Brook Reserve Native Plants

(From. Lindgren.E. "Plant Ecology - Warbrook Rd and 21 mile peg Pseudemydura Reserves" in Reference 1)

Characeae	Chara australis	(c)
Polypodiaceae	Cheilanthes tenuifolia (Burn) Swartz.	
Gramineae	Neurachne alopecuroides RBr.	(c)
	Stipa compressa RBr.	(c)
Cyperaceae.	Isolepsis marginata (Thunb) A. Dietr.	(c)
	Schoenus minutulus F. Muell.	(c)
	Chorisandra enodis Nees.	(c)
Restionaceae.	Leptocarpus canus Nees.	
Philydracaea	Pritzelia pygmaea (RBr) F. Muell.	(c)
Liliaceae	Burchardia umbellata RBr	(c)
	Thysanotus tenellus Endl.	(c)
	Thysanotus patersoni RBr	(c)
	Arthropodium callilipes Endl.	(c)
	Chamaescilla corymbosa (RBr) F. Muell.	
	Tricoryne elatior RBr.	(c)
	Caesia parviflora	(c)
	Corynotheca micrantha (Lindl) MacBride	(c)
	Stypandra grandiflora Lindl	(c)
	Sowerbaea laxiflora Lindl	(c)
	Borya nitida Labill.	
	Xanthorrhoea preissii Endl.	(c)
Haemodoraceae	Haemodorum spicatum RBr	
	Haemodorum paniculatum Lindl.	
Amaryllidaceae	Hypoxis occidentalis Benth.	
	Tribonanthes variabilis Lindl	(c)
	Anigozanthos bicolor Endl.	(c)
Orchidaceae	Thelymitra flexuose Endl.	(c)
	Thelymitra antennifera (Lindl) Hook	(c)
	Thelymitra crinata Lindl.	(c)
	Diuris longifolia RBr	(c)
	Diuris carinata Lindl.	(c)
	Prasophylum fimbrea Reichb.	(c)
	Prasophylum cyphochilum. Benth.	(c)
	Caladenia menziessii RBr.	(c)
	Caladenia filamentosa RBr.	(c)
	Caladenia flava RBr.	(c)
	Caladenia patersoni RBr var longicauda (Lindl) Rogers	(c)
	Caladenia gemmata Lindl.	(c)
	Glossodia brunonis Endl.	(c)
	Glossidia emarginata Lindl.	(c)
Proteaceae	Hakea varia RBr.	(c)
	Hakea prostrata RBr.	(c)
	Dryandra nivea RBr	
Droseraceae	Drosera gigantea Lindl.	(c)
	D. menziesii RBr.	(c)
Mimosaceae	Acacia saligna Lindl.	(c)
Papilionaceae	Isotropis cuneifolia (Sm) Domin	(c)
	Jacksonia sternbergiana Hueg.	
Papilionaceae	Eutaxia virgata Berth.	
Geraniaceae	Erodium cygnorum Nees	
Euphorbiaceae	Phyllanthus calycinus Labill.	

Dilleniaceae	Hibbertia stellaris Endl.	(c)
Myrtaceae	Eucalyptus rudis Endl.	
Myrtaceae	Melaleuca lateritia Otto	(c)
	Melaleuca rhaphiophylla Schau	
	Melaleuca uncinata RBr.	
	Melaleuca viminea Lindl.	(c)
	Verticordia densiflora Lindl.	
	Kunzea recurva Schau.	
Halorrhagaceae	Myriophyllum sp.	
Umbelliferae	Hydrocotyle callicarpa Bunge	(c)
	Hydrocotyle lemnoides Benth	(c)
Gentianaceae	Villarsia capitata Nees	(c)
Lentibulariaceae	Polypompholyx multifida (RBr) F. Muell	(c)
	Utricularia hookeri Lehm.	(c)
Goodenicceae	Dampiera coronata Lindl.	(c)
Stylidiaceae	Stylidium petiolare Sond.	(c)
	Stylidium pulchellum Sond.	(c)
	Stylidium perisceliantum Erickson & Willis	
Compositae	Brachycome iberidifolia Benth	
	Helipterum cotula (Benth) DC	
	Podolepsis lessonii (Cass) Benth.	

(c) Found in claypan areas

APPENDIX 7.8 Revegetation sequence

The priorities of this component of the rehabilitation are, in order of decreasing priority:-

1. Maintaining low water nutrient concentrations, reducing water suspended solids, and keeping inundated areas weed free.
2. Rapidly reducing sources of weed seeds, and eventually eliminating them.
3. Rehabilitating the soils and vegetation of the north west section.
4. Revegetating the seasonally damp areas around the wetlands, and on the constructed banks.
5 Rehabilitating the vegetation and soils of places where the water moves.
6. Rehabilitating the vegetation and soils of the remainder of the reserve.

The priorities in the program below were selected on the assumptions that the earthworks would also proceed as recommended, and that tortoise would not be released before 1998.

They were also influenced by knowledge of the increased difficulty of removing weeds from around retained water, compared with a seasonally damp area, and the need for the program to be seen to be making an improvement.

If the above cease to apply the priorities may need resetting.

Whoever directs the rehabilitation program will need to be prepared to spend a long time associated with the task, as continuity is important in such a slowly developing situation.

The first task is to <u>prepare:-</u>

Assess the suggested zones and make weed status evaluations

Mark all the existing significant native plants, or plant regions. A brightly painted steel post, eg star picket, is recommended.

Build up the information base. This should include:-

animals seen on the site

plant list; pressed specimens of weeds and native plants. Photographs, and diagrams for field use can be helpful.

Details on biology, esp.. susceptible stages, of weeds, and their defence mechanisms. eg seed production and dissemination; regeneration of root; shoot; cuttings.

Responses to fire; slashing; and appropriate herbicides.

Soil:- significant differences in the zones, and relevance to plants, and run-off.

Evaluate the resources, and decide on achievable goals.

Collect seed, and process it, including adding insecticide, and probably fungicide.

Order seedlings (up to 18 months lead time may be needed).

Train field workers/volunteers in:-

plant identification; use of herbicide wiping techniques - safety and no spill methods; weed eradication techniques; appropriate methods for seeding and planting out.

Select tasks/targets the volunteers can achieve

Budget for:- a. big sessions at times when these are need for major weed eradication and seedling replantings

b. ongoing follow-up - reweeding; monitoring; watering; advancing the weed-free front; trials of alternative techniques for difficult situations.

Record observations; actions and results. Take photographs (documented), before the start of each task, and of key sites at least every two years. These provide support for scientific, and motivational programs.

<u>Implementation Program</u>

YEAR 1 (1995)

Priority 1: Preparation, planning, and monitoring (and record) the full year's weed successions. This includes marking all the significant native plants in the reserve.

Priority 2: Establishing the boundaries. As well as earthworks, eradicate weeds of Zone 6 and the eastern sections, with immediate replanting (in 0.5mx0.5m cleared plots), the

20 - 30m strip adjacent to the fire breaks.

First pass:

Timing: as early as will ensure good eradication of Cape Tulip,Guilford Grass, and Paterson's curse.

Method: Light weight machine blanket wiping, eg a 4 wheeler motor-cycle.

Preferred herbicide: Glyphosate (preferably not Roundup, but a no- or low- surfactant formulation).

Replant and mark: Seedlings of Acacia saligna, first three rows, as close as 1m centres, and Hypocalymma angustifolium understory.

Inside these, plant (in appropriate soils and expected water regimes), Hakea prostrata; Eucalyptus calophylla;, E. rudis (a few adjacent to wet areas), Viminaria juncea; and possibly Dryandra sessilis, and other taller plants growing in Ellen Brook Reserve [1], (Appendix 7.7).

Consideration should be given to clearing and marking plots of land, and sowing with "under-story" seed. (eg Isolepsis cernua, Melaluca viminea, (near water), Kunzea recurva, Hakea varia, and the Liliaceae of the region.

Second pass:

Timing: before the Rye grass develops viable seed (ie approximately. September).

Method as before.

Herbicide: Fusilade.

Priority 3: Establish a stable baseline for Zone 1, by eradicating all weed sources in the North and West fence lines.

Commence regular weed eradication, and replanting with appropriate pioneer and semi pioneer understorey, and potentially dominant seedlings. Thin A saligna as planting progresses.

Priority 4: Commence weed eradication in Zone 3, esp.. portions to be excavated in year 2. This work probably need not start until later in the season.

Principal weed targets: rye grass; paspalum; Rumex sp.; and particularly kikuyu.

Method: Spot spray; and hand wipe solitary occurrences.

Herbicide: glyphosate (no- or low- surfactant). **See note 2 Wetlands.**

YEAR 2

Priority 1: Maintain growth of marginal trees (East and Zone 6)

In 1996, there could be a heavy regrowth of all the existing weeds. In addition likely migrants into the semi-cleared area will be : Ixia sp; Veldt grass; Brizia sp; Trifolium sp; Oxalis sp. and possibly Paspalum sp. These will need to be dealt with as, and when, they appear, until a good belt of Acacias and understorey are developed.

In June blanket wipe the weed regrowth with Brushoff, using a lightweight machine. If autumn trials have shown the native plants tolerant to Brushoff at the proposed concentration then the whole area can be wiped. If not, the wiping will need to be circumspect, and supplemented by hand wiping, or slashing/uprooting, before the Cape Tulip and Guilford Grass start to form new "bulbs".

Allow 3 weeks before further planting in treated areas.

Priority 2: Continue with Zone 1. Consider introducing, at the end of the year, small quantities of dried mud from the Ellen Brook Reserve wetland successions, to reintroduce Drosera; trigger plants; and both species of bladderworts, to the newly created wetland margins.

Priority 3: Continue wetland weed eradication, particularly around G8, and commence wetland replanting eg Melaluca lateritia in Zone 2. Also note if transplanting of any of the existing claypan plants of Zone 2 is needed.

Year 3

Priority 1: Maintain growth of marginal trees. Continue replanting: evaluate if low labour weeding needed. Otherwise just use minimum weed control around the existing plantings, until the main revegetation program reaches the area.

Priority 2: Continue Zone 1 revegetation, and if recovery is fast enough move on into Zones 2 and 3.

Priority 3: Finish weed eradication and replanting around the wetlands,and commence to revegetate outwards from these centres.

SUBSEQUENT YEARS:

Continue weed eradication in the sections already replanted, and start planting the more sensitive (?climax) understorey shrubs and herbs.
Continue to spread out from the existing centres, eradicating weeds, planting climax dominants and pioneer understorey plants.
Continue thinning A saligna , and replacing it with a range of other trees. In about 5 - 10 years the boundary A saligna will need to be reviewed. The wall will need thinning and possibly replanting with less pioneering small tree species.

Future activities need planning at this stage, and will every 5 to 7 years thereafter.

NOTES

1. WEED ERADICATION TECHNIQUES.

In Reserve A42126 the only techniques available are those of a mowing or slashing type, either to prevent seeding or exhaust root reserves; uprooting; using appropriate herbicides; or habitat alteration to allow natives to out compete the weeds.

Weed suppression eg by heavy mulching; burning; and ploughing or ripping are incompatible with the aims of the program.

2. WETLANDS.

Exercise great caution when using herbicides near the water : toxic effects from either active ingredients or surfactant are likely, especially on frogs (touching the vegetation) and tadpoles.

* Weed growth around wetlands is particularly difficult to control, largely because of the large number of stoloniferous and similar hardy plants that flourish there.

* W.A. Dept. of the Environment has observed heavy frog deaths after spraying marginal vegetation with Roundup. Tadpoles are killed by low/moderate concentrations in water. The harmful ingredient is more likely to be the surfactant - a common component of most herbicides.

* Wetland Weed control in Reserve A42126 needs very careful planning to minimize frog or tadpole deaths. Logically the times to use herbicides are when the frogs are under ground, or when the next generation are in eggs or tadpoles (assuming no water contamination).

3. WEEDING AMONG REMNANT SEDGES.

A major weed eradication problem could arise at the stage of eradicating the weeds, mainly Guilford grass, from the remaining sedges around the claypans as hand weeding would be extremely slow. Preliminary investigations and trials of selective herbicides are needed. Wiping trials with Brushoff or Glean, or Weedazol TL plus, to determine if the sedges are resistant at concentrations toxic to the weeds.

4. SOURCES OF REPLANTING MATERIAL.

Two WA nursery groups have specialized in plants for bush and wetland revegetation;
Apace Aid Inc, Winter House, Johannah St, N.Fremantle, 6159 WA.
Ecosystem Management Services, Lot 6, Della Rd, Noranda, WA.
Both offer a range of services including collection and germination of seed from the client's habitat.

Largely by chance we have had more contact with Apace Aid, and on this basis we sought an uncommitted expression of their interest in working with CALM on revegetation of A42126. They are interested, on a commercial basis (not discussed), and if requested would like Melaluca lateritia and Hypocalymma angustifolium seed as soon as possible. This is not a recommendation for Apace, although we have found they do deliver the goods, but so too do Ecosystem Management. Ecosystem Management may be a better source of Restionaceae, as they are working on tissue culture sources of these difficult to germinate plants.

APPENDIX 7.9 Notes on Weed Biology, and Herbicides.

The following is information collected during the project which may be useful for the rehabilitation team leader.

A Weeds

The most prominant weeds observed over the period September - October 1994 were:-

Cape Tulip
Guilford Grass
Ixia sp
Wimmera Rye Grass
A 200 - 300mm tall grass (possibly a native)
Brizia sp.
Oxalis sp.
Paterson's curse.
Trifolium sp.
Around the wet areas, particularly the north east, the following were growing:-
Kikuyu
Paspalum
Couch
Rumex sp
and Guilford Grass.

Roadside Seeding (Main Roads Dept)

Low success rate with direct seeding on clay, even after late summer ripping and cultivation to obtain finely divided surface.

Better results obtained using this technique on less finely textured soils.

Better results obtained on clay by planting seedlings (from tubes, or else germinated in soil with similar water reteative properties).

Some residual herbicides e.g. Atrizine, are trapped in the top 1 or 2 cm of soil, and if this is removed and left aside, replanting in the resultant depression is successful. This is unlikely to be the case with Brushoff which is readily transported in soil water.

One leaf Cape Tulip (*Homeria flaccida*).

Bulb dormancy is variable; breaks down due to high temperature fluctuations; burning the litter is one way of increasing the temperature range. Sprout then emerges from bulb and waits, and once rain comes grows on. Dormancy could be a long time; possibly >10 years.

Seed generally only lasts 12 months, usually then rots if not germinated. In normal paddock little of germinating seed makes it through the summer, due to competition for water and light; in wetlands or when advancing into uncolonized territory it may be more important as a colonizer.

Seedlings that survive will usually produce seed in its second year, certainly in its 3rd.

New bulb starts to develop at the stage when the old one is exhausted. need to look and see when this is occuring

At this stage the plant is vulnerable to slashing, but because of the spread in growth rates not all a field crop will be equally exhausted and this technique would need to be repeated for a number of years.

Sulphonyl urea herbicides are effective at low concentrations eg blanket wiping (to leaves) can use as little as 10g of product (ca 6g active agent) per hectare.

Sulphonyl urea herbicides can be used with good effect between June and September. Commercial 4 wheel motorcycle blanket wipers are available.

Ag Dept library has a thesis by Geoff Pearce that covers much of the biol of Cape Tulip. (John Peirce).

Can successfully wipe Cape tulip with Glyphosate/Roundup. Machine wick wiping spills less than manual wiping. Herbicides give better kills than cultivation, but slashing just before flowering,at ground level, and picking up tops as well, also reduces infestations. Control is needed for 5 - 10 years to pick up all bulbs.

Cape tulip will spread slowly through virgin bush. It's a tough weed. It does not favour permanently wet areas, but will grow in sesonally wet places. It can grow more strongly in dappled sunlight. (F.Ramsden.)

B Herbicides with the potential for dealing with some of the present major weeds; but also with potentially serious ecological side or after effects.

GLUPHOSONATE Agents:- Hoechst Scherring AgrEvo Pty Ltd.
Currently under investigation by the Agriculture Dept. for Cape tulip control.
V. similar to Glyphosate, but not translocating: appears to produce NH_3 in the plant.
Designed for orchard weeds; can't be wiped, must be sprayed; which means plants need fairly extensive coverage (means there will be spillage on the ground.)
Kills Cape tulip and guilford grass.
Very stable in water (expected from a phosphonate.) (Geoff Perking, Melbourne)

FUSILADE Fluazifop butyl. Manufacture ICI.
A translocating, post emergent herbicide for grasses. Must be applied to actively growing plants.
Normal application rates 500mL (ca 0.25kg a.i) to 2 or 4L (1 - 2kg a.i) per hectare.
Recommendation for dense advanced ryegrass 1L per hectare.

1 Manufacturers information is very general, but includes:-
Breakdown - "rapid" in soils. t1/2 Fluazifop butyl ---> Fluazifop 1 week,
Fluazifop ---> degredation products ≥ 3 weeks.
Temperatures not specified, but residualsoil effects on weeds between 3 and 6 weeks, depending on temperature and moisture.
Toxicities:- (Fluazifop butyl) Mallard duck; acute oral LD 50 > 17,000mg/kg;
Bluegill sunfish 90hr LC50 0.53mg/L;
Daphnia (?sp) "unlikely to be affected";
Earthworms "no effect" (Field populations not significantly different 12 months after application of >2 times maximum recommende rate).

2 Kings Park
Used as a blanket spray over native plants for control of Veldt grass. Rate of 2 - 4L/Ha used in early work, and the only native plant harmed was *Microlaena stipoides* .
(NB Kings Park contains *Isolepsis marginata* and *I. cernua*..)
WA Wildflower Soc. Newsletter (1987), 25, No.1.

3 Swan River Trust
In Dec 1991 hand sprayed at a rate of 1kg a.i ha^{-1} to shore line Juncus kraussii, Isolepsis nodosus, Sarcocornia sp and a range of weeds, including couch, kikuyu, and buffalo grasses.
In March 1993:- No visible effect upon native plants, but most strongest grasses eradicated and only ca 5% of kykuy regrowth.
No significant detrimental herbicide effect over 6 days on either terrestrial or bottom dwelling aquatic invertebrates (the aquatic invertebrates were molluscs (4 spp); polychaeter(6 spp); crustaceans(9 spp) and insects(1 sp).
Swan River Trust Report No 12(1993).

Eradication of Cape Tulip and Guilford Grass with SULPHONYL UREAS

The sulphorylurea herbicides Glean (chlorsulfuron) and ally/brushoff (metsulfuron methyl) which are regularly used for agricultural eradication of these weeds are contra indicated for Ellen Brook for the following reasons.

1. Manufacturer's published toxicity data shows a 48 hour LC_{50} for Daphnia (probably D. magna, - but indicative for all crustacea) of 370ppm(Glean) and greater than 150ppm(Ally).

Unpublished and commercially sensative work from Du Pont's laboratory gives an LC_{50} for D carinata of > 300ppm.

2. Solubility at pH7 and 25^0 is variously estimated by the manufacturer as 7,000ppm (Glean) and 9 500 or 109 ppm (Ally/Brushoff) i.e. possibly greater than 10 times above the crustacean LC_{50} values.

3. Both Glean, and Ally / Brushoff (Metsulphuron methyl) are mobile in soil water; not significantly bound to soil fractions; and only slowly degraded with rates of removal dependent on pH; temperature; and bacterial activity, but ranging from minimum half lives of 2-4 weeks at 30^0 and pHs around 7.

($t_{1/2}$ for sterile hydrolysis at pH 7, 25C est. as 1000 days, ie $2^1/_2$ - 3 years. Could expect to halve this in bacterially active soil; but also depends on temp and moisture. In another document an estimate of the hydrolysis half life is only 111days at pH 7).

However persistence studies have shown detectable plant effects after 12 months. At these rates concentrations exceeding LC_{50} would exist for at least 5 half lives i.e. minimum times of 10 - 40 weeks to kill less than 50% and this does not consider sub -lethal effects.

4. The crustacea constitute the major meso-fauna food supply : Cladocera, frequently dominate the herbivour path; Ostacods and Phreatoicids the detrital path.

5. Both herbicides are applied either as granules or wettable powder : there is considerable likelihood that despite the low dosage rates needed there will be too much solid herbicide not taken up by the plants, and available for, subsequent transport into the water bodies.

6. Aquatic solutions of either herbicide must be expected to reduce phytoplankton since plant protection from these chemicals depends upon the species ability to remove the herbicide from its tissues before it reaches the places of cell division.

7. While Glean and Ally are very effective on sprouted cape tulip and Guilford grass, the former plant needs at least 2 annual follow up treatments, because of dormant corms. Longer dormancy in uncultivated soils is reported in Weeds of Western Australia.

(Du Pont published and commercially confidential documents)

(We acknowledge with thanks,the provision of confidential information by Du Pont.)

Withholding period before planting eucalypts after wiping with BRUSHOFF.

After spraying with Brushoff in SW, on soils of pH 3-4, CALM allow two days per g of herbicide per hectare, before re-planting eucalypts.

Withholding time very dependent on pH and soil organic content.
At pH 7-8 (probably that of Ellen Brook) must allow much longer before replanting. Low organic content of Ellen Brook soils would also increase withholding time.

WEEDAZOL TL plus Agents Ciba-Geigy

Translocating herbicide registered for agricultural spraying for among others:- <u>Typha</u>, <u>Phragmites</u>, Victorian nutgrass, <u>Oxalis</u>, <u>Watsonia</u>, Guilford Grass, dock, and Kikuyu.

Defender Bio-speed or SPEEDWEED herbicide. Agents: Edward Keller (NSW).

Available from supermarkets in a spray pack.

Non selective organic, ready to use, rapid acting herbicide. Low animal toxicity, non persistent, low aquatic solubility; but being a mixture of fatty acids it could float on the surface of water and reduce its oxygenation.

Active ingredients:-fatty acids; decanoic acid and potassium decanoate; works by dissolving the waxy layer on leaves, leading to plant necrosis.

APPENDIX 7.10 Comments on Field Chemical Monitoring Kits.

1. Disadvantages

- capital cost (about $2000.)
- extra for field worker to maintain, to carry and use (ca 30 minutes for the first determination & 15 min each subsequent one, and then cleaning time).
- not very great precision.
- untrained operator can end up with misleading, even imposible, results.

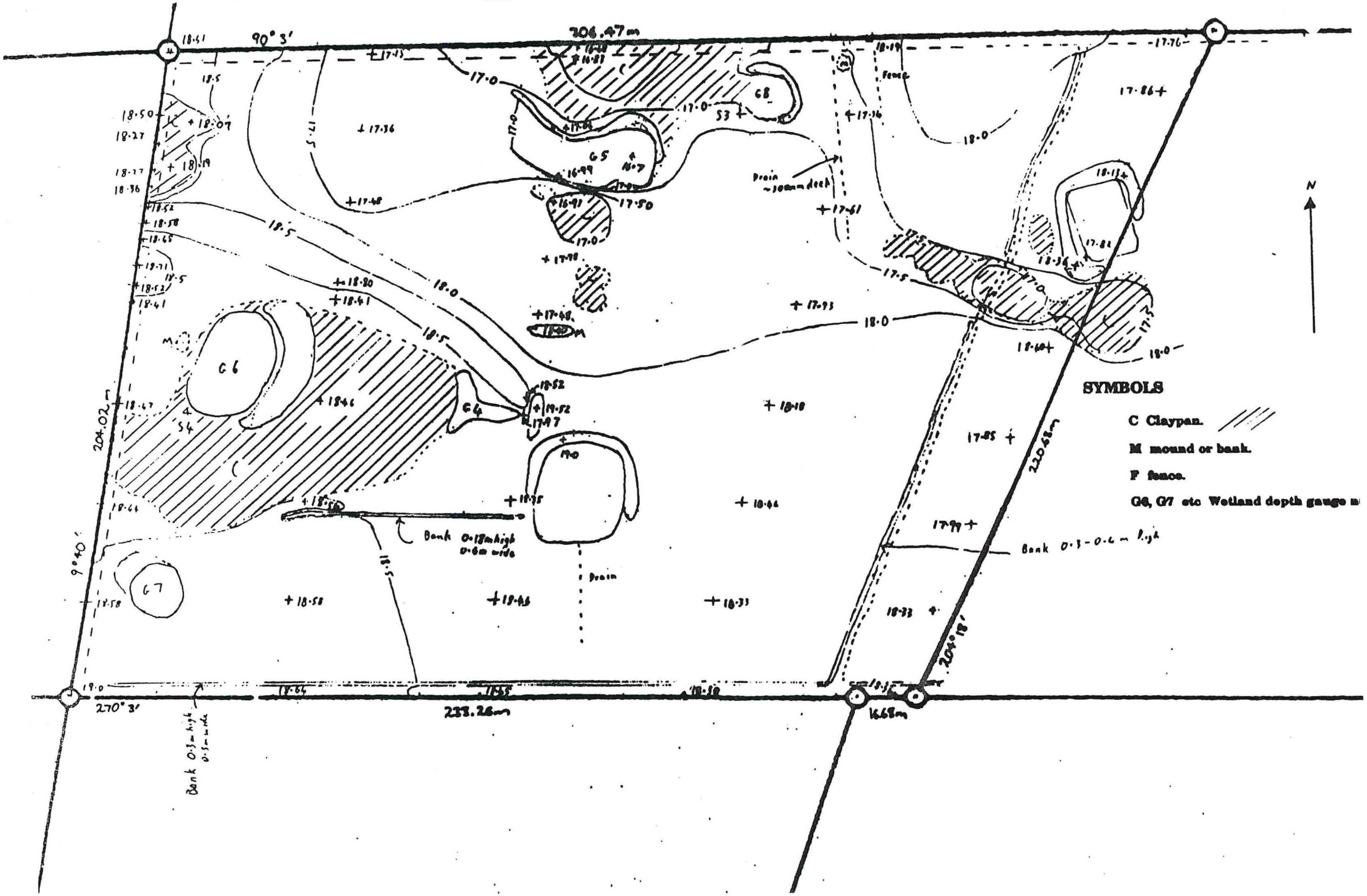
2. Advantages

- speed of result
- ease of on the spot checking of discrepent situations and results in the field.
- Very low running cost, estimated about $1 per determination, for materials.
- versatile - can do range of water and soils tests, (these include reactive phosphorus; pH; and ammonia).
- Precision usually adequate for management since the precision is seldom less than genuine or significant changes.
- Scientifically robust - can even do some determinations effectively on unfiltered but slightly cloudy water.

Recommend :

i Intended operator first do some tests in analytic laboratory, with an experienced analyst to point out significant features, then use the kit on prepared standards.
ii Operator run prepared standards 1x or 2x per year, as a check on the instrument.
iii Once a year a set of duplicate samples also be analysed by a recognized lab to ensure equipment and technique are still performing accurately.
iv Equipment be cleaned at immediate end of field work (include wash bottle in the field kit).

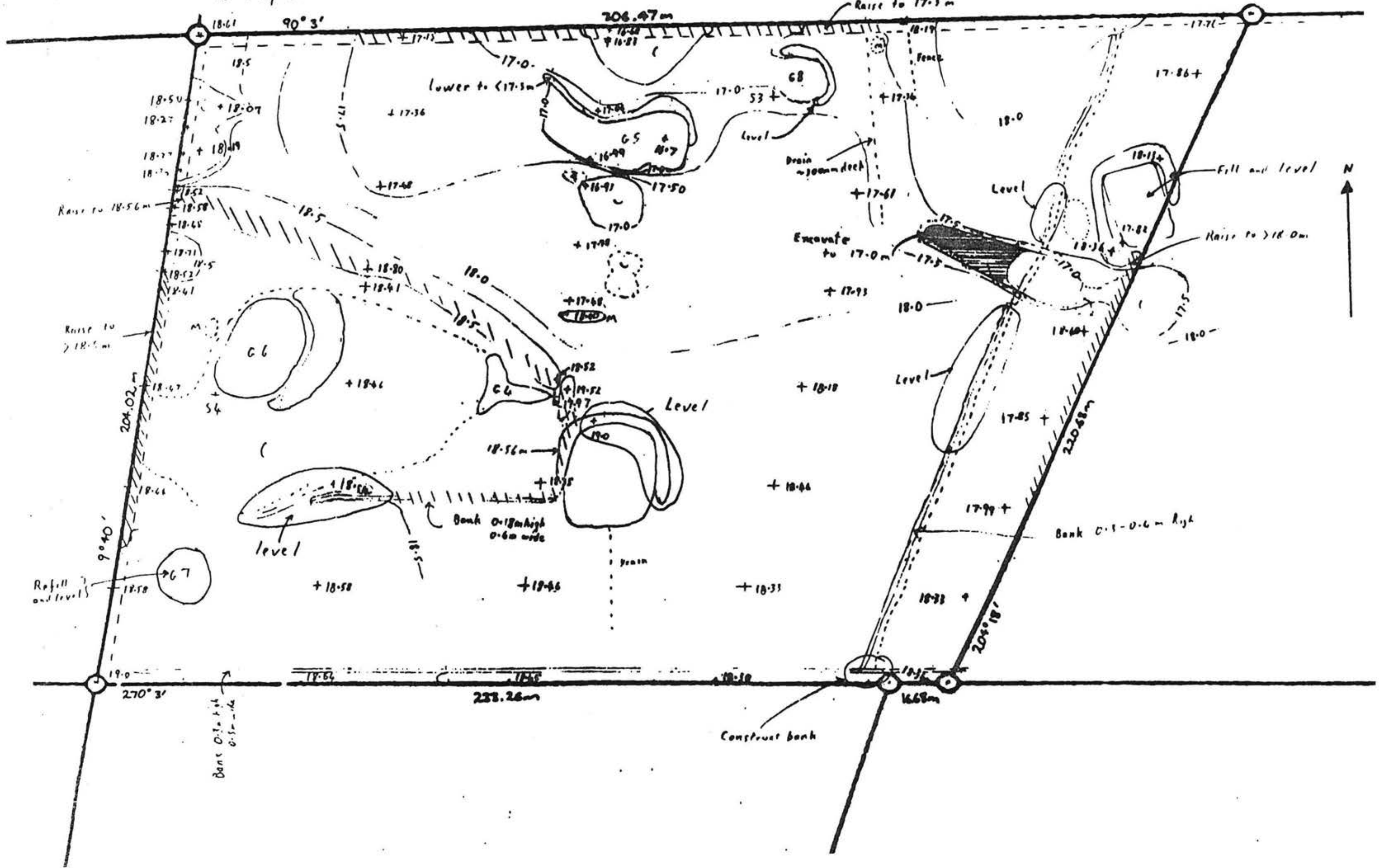
SE A4
Scale 1:1000
FR and PM Lantzke 1994



8. Map 2

RESERVE A42196
Scale 1:1000

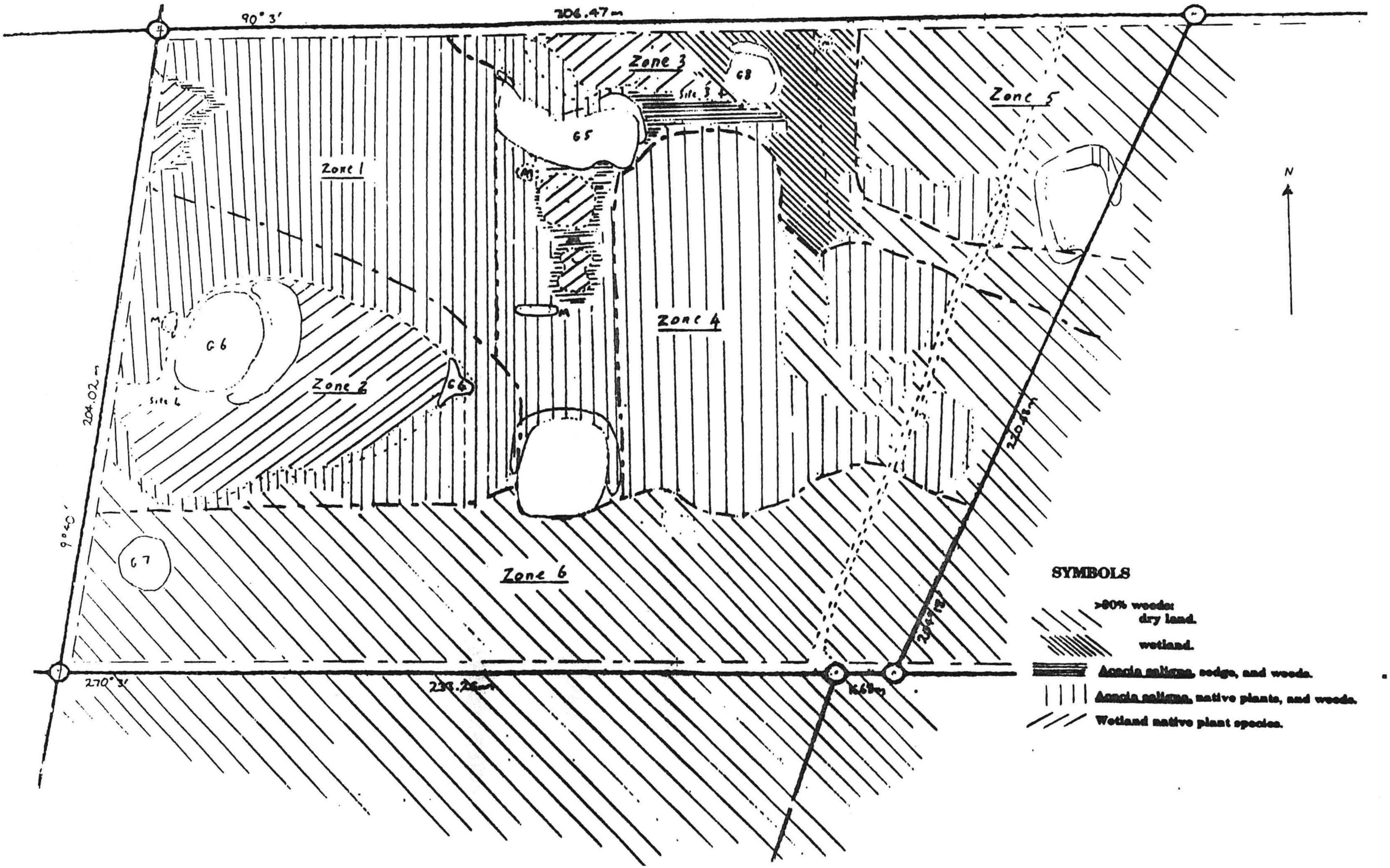
Proposed Earthworks



8. Map 3

RESERVE A42126
Scale 1:1000
(1:1414 A4 size)

Vegetation
IR and PM Lantzke 1994



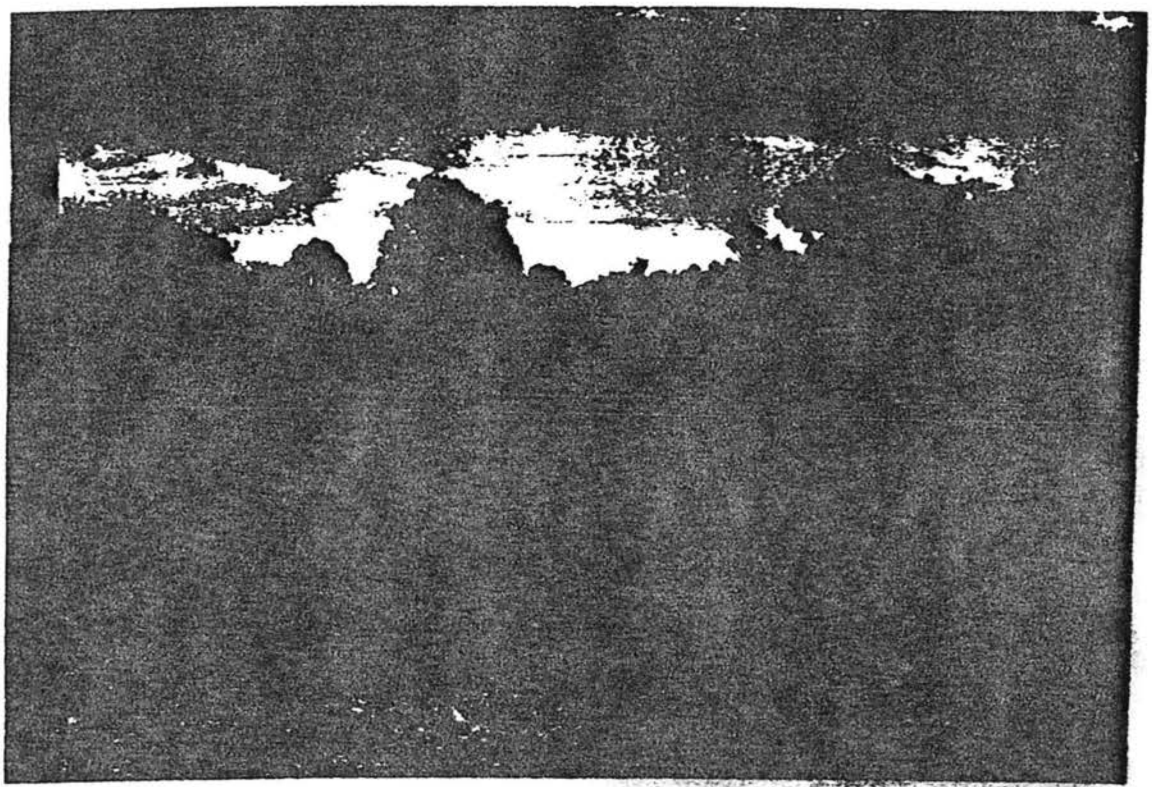


Plate 1 Ellen Brook Reserve Site 1
11/10/94

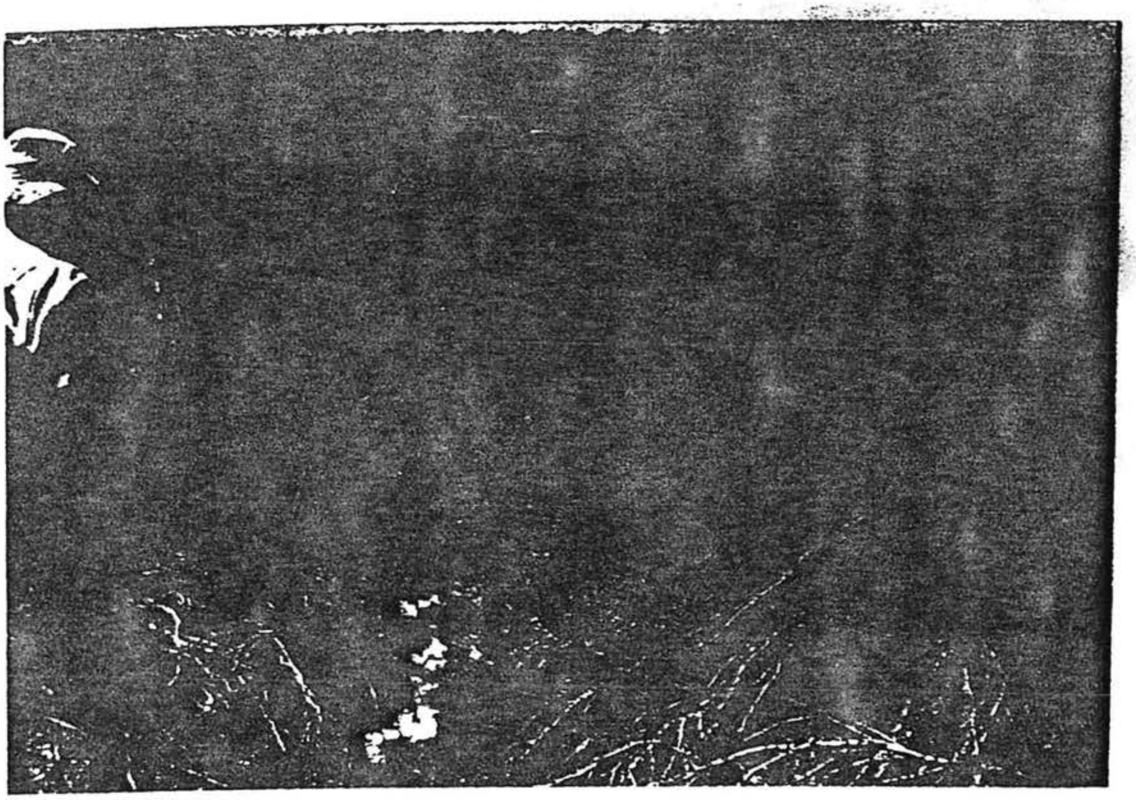


Plate 2 Ellen Brook Reserve Site 2
11/10/94

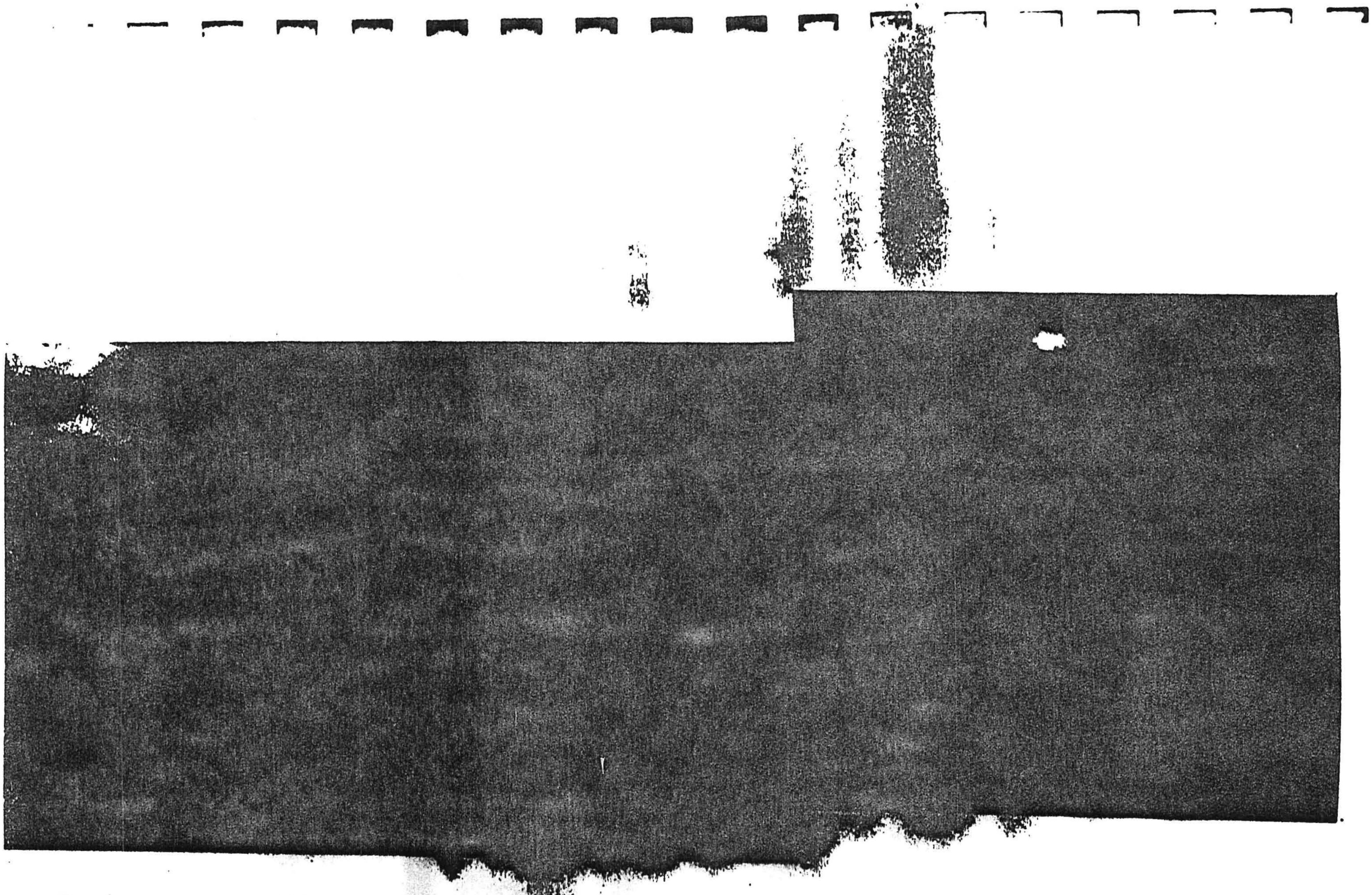


Plate 3 Reserve A42126

Western fire break and part of Zone 1. from NW corner.

10/8/94

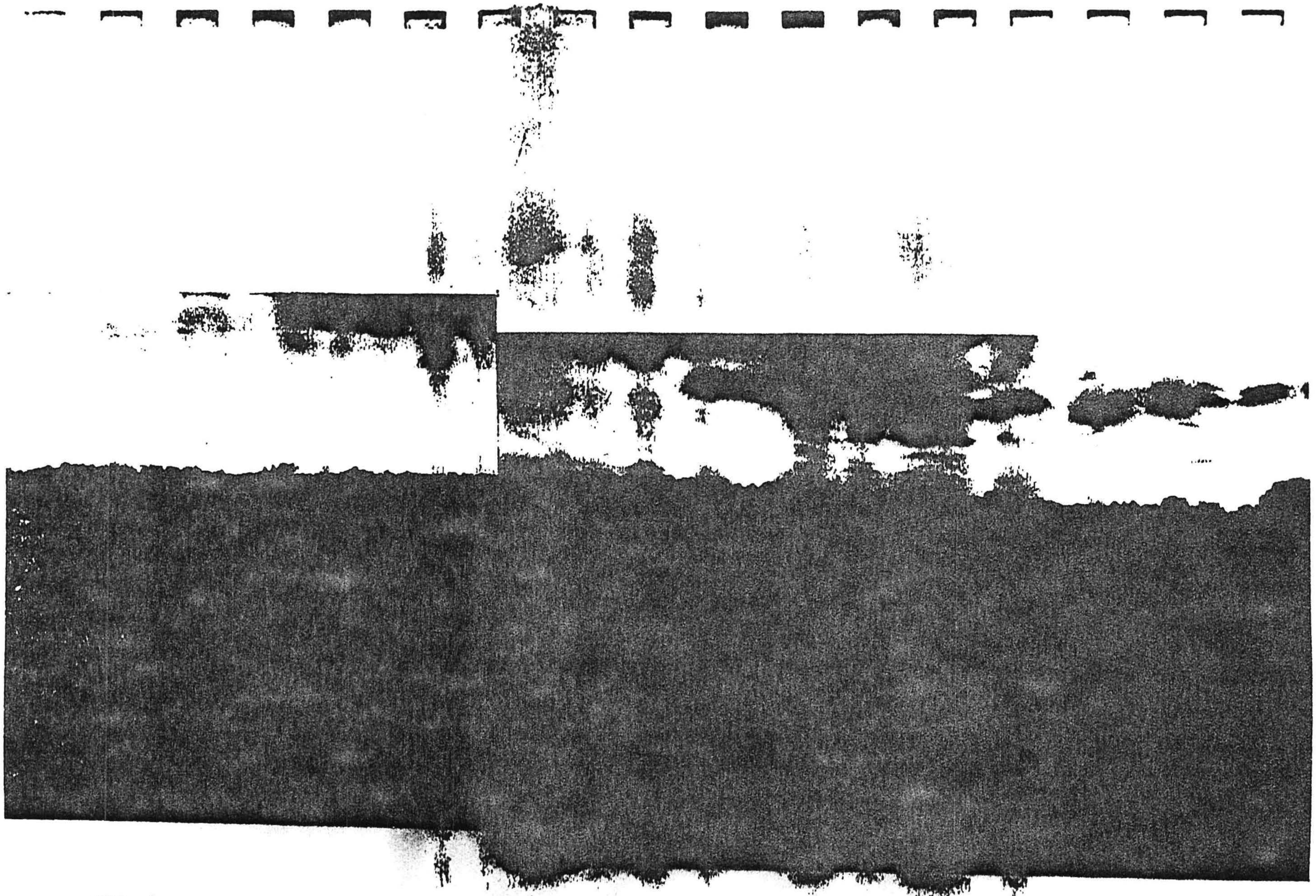


Plate 4 Reserve A42126
Northern fire break and part of Zone 3 from the NE.
27/9/94

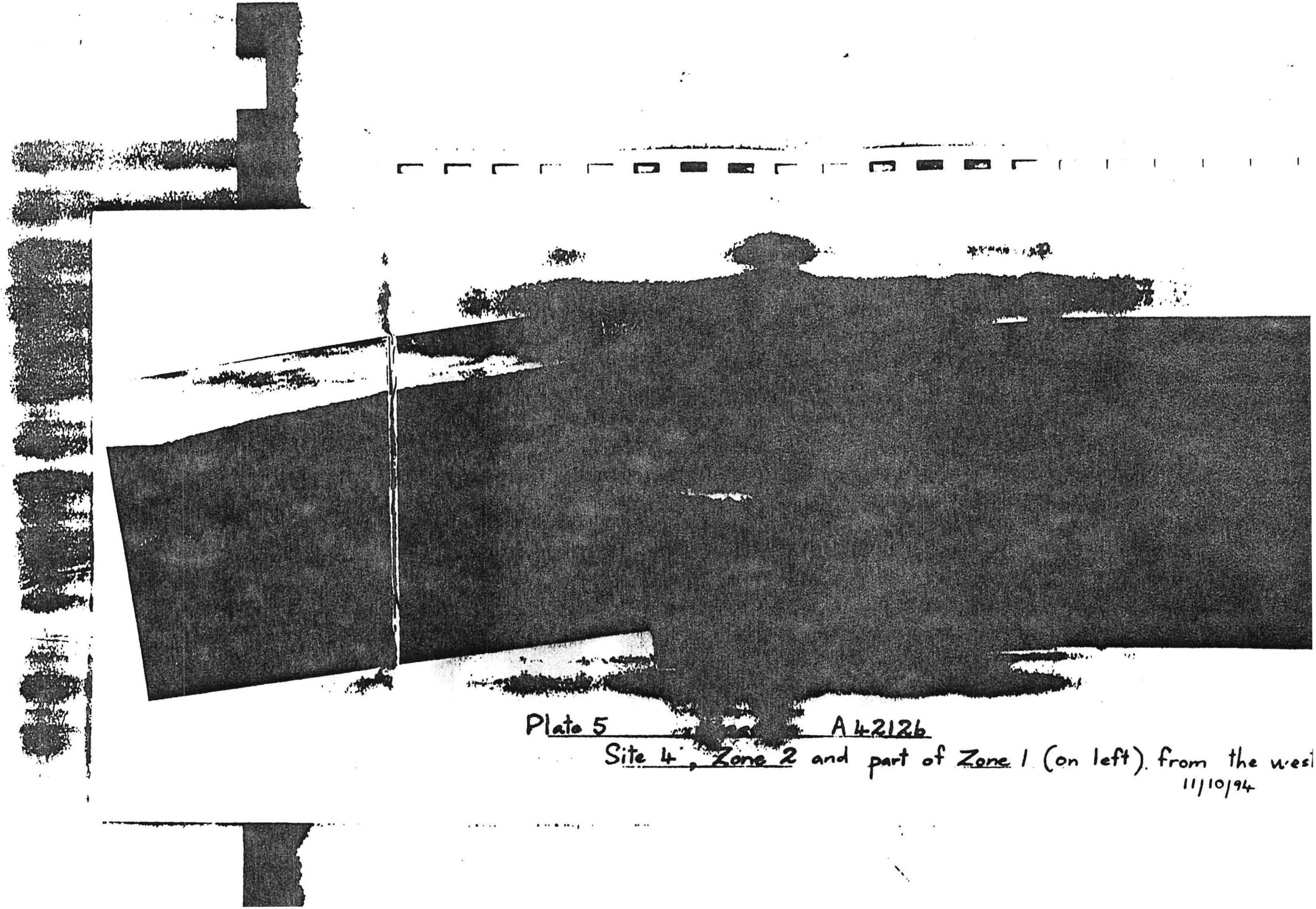


Plate 5 A 4212b

Site 4, Zone 2 and part of Zone 1 (on left) from the west
11/10/94

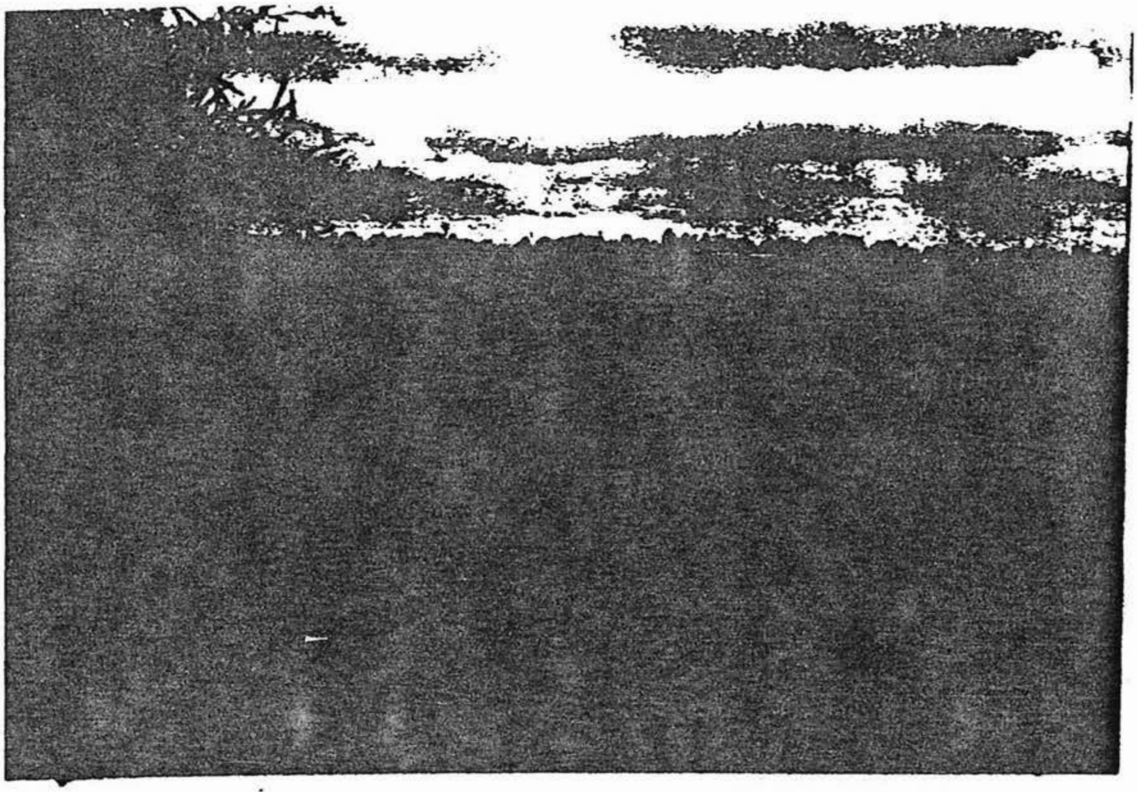


Plate 6 Reserve A42126
Zone 6, from the West.
27/9/94