MANAGING SOIL NUTRIENTS IN RESIDENTIAL AREAS OF THE SWAN COASTAL PLAIN

A Preliminary Report Prepared by the Chemistry Centre (WA)

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EXECUTIVE SUMMARY

A limited survey of soils from residential gardens in the Perth metropolitan area has shown that most soils contain excessive concentrations of phosphorus (P). The additional phosphorus is believed to result from widespread addition of organic manures, composts and commercial landscaping blends. Inorganic fertilisers may also contribute to the excess P load. High concentrations of P in commercial landscaping blend are caused by addition of materials such as ‘biosolids’ and animal manures.

Many soils contain marginal or deficient amounts of potassium, an essential element for plant growth. This imbalance is caused by the widespread use of animal manures (which usually have low potassium concentrations), or inorganic fertilisers based on nitrogen compounds (eg, urea).

Current management practices, based mainly on addition of organic materials, have resulted in soils with near neutral pH values, increased nutrient content, and a tendency to become non-wetting (hydrophobic). Significantly, these practices have resulted in reduction of the ability of the soil to retain phosphate, indeed approximately 30% of the soils analysed are completely saturated by P. This observation is particularly important in terms of sustainable land management for the coastal plain as it indicates that these practices may eventually lead to contamination of groundwater and coastal lakes and rivers by leaching of P from the topsoil. Although the area covered by garden soils is relatively small, the very high nutrient loadings may provide ‘funnels’ to the groundwater in situations were the depth to groundwater is small, and the subsoils also have low P adsorption capacities. Such conditions are common in the Bassendean series of the coastal dune system of the Swan Coastal Plain.

Improved soil amendment materials for use on sandy soils of the Swan coastal plain will need to have a higher clay contents and significantly higher P adsorption capacities. Either natural clays or industrial by-products such as bauxite processing residue (‘red mud’) can provide these attributes. Further work will be required to determine optimum rates of incorporation of these materials in commercially available soil blends.

Sustainable land management on soils of the Perth Metropolitan area will only be achieved when such materials become available. To increase the effectiveness of improved blends and management practices, it is recommended that more stringent environmental management conditions be imposed on new residential developments, and an educational campaign be undertaken to provide better advice for existing households.

Provided sources of funding are identified, the Chemistry Centre (WA) is prepared to undertake the research necessary, in collaboration with other State Government agencies, local government councils and industry, to achieve these goals. Several stages of research, product development, extension to the landscaping industries and education of the general, all requiring additional funding, have been identified:

- A more extensive survey is recovered to provide a better indication of the extent and magnitude of saturation of garden soils with phosphorus and other nutrients. The survey would be extended to include other nutrients such as forms of nitrogen and trace elements. Collection and analysis of samples of subsurface soils are also required to determine the extent of leaching of nutrients from the topsoils. The estimated cost is $400 to $600 per site.
- Sources of suitable amendment materials need to be identified and characterised. These materials would include natural clays from locations close to the Perth metropolitan area, and industrial waste materials such as bauxite processing wastes, fly ash, gravel fines, organic wastes and mineral sand processing residues. The estimated cost is $5,000 to $15,000.
- Working with the landscaping supplies industry, the Chemistry Centre will develop and evaluate new soil blends. A request for funding for $50,000 has already been submitted to the DEP Waste Minimisation and Recycling Fund. The estimated cost for this phase of the project is $50,000 to $150,000.
- Dissemination of the results of this work to the landscaping and garden nursery industries and to the general public is expected to be a collaborative effort with the Water and Rivers Commission and will involve the media and local councils.

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1. INTRODUCTION

1.1 Background

The Perth Metropolitan area is unique among Australian cities, and possibly in the world, in that is located on an extensive infertile sandplain. Coupled with the high nutrient input and the high winter rainfall, a very high proportion of the nutrients applied to the recreational parks, sporting facilities and home gardens on these soils are lost by leaching. These leached nutrients eventually find their way into coastal lakes and rivers, causing widespread environmental problems by promoting excessive algal growth. As a result of nutrient enrichment, the Swan-Canning River system, and the Peel-Harvey Inlet are currently having major problems with excessive growth of both macro algae and toxic microalgal blooms.

Even on a world scale, the Perth Metropolitan area is extensive, stretching more than 100 km from north to south along the coast, and more than 20 km inland. The main reason for this is the relatively large size of suburban residential blocks, typically 500 to 800 m^2. Most of these blocks support large areas of turf and gardens, both native and exotic.

The sandplain soils are characterised by extremely low fertility, poor nutrient retention and low water holding capacity. Maintaining an attractive garden and lawn requires large inputs of nutrients and soil amendment materials.

1.2 Nutrient Management on the Swan Coastal Plain

The inputs of nutrient on an area basis of the domestic gardens is much higher than that of the surrounding rural areas. Loss of nutrients by leaching from theserural areas, which support a range of various animal and plant industries, has been shown to be responsible for the nutrient enrichment of the Peel-Harvey inlet system, and also the Ellen Brook catchment of the Swan-Canning system. The high nutrient input in the metropolitan area is believed to be partly responsible for the poor condition of the Swan-Canning system, and largely responsible for the nutrient enrichment of several coastal lakes such as Lake Monger and Bibra Lake (Figure 1).

Perth also relies on high quality groundwater for much of its domestic and industrial water supply. Approximately 50% of Perth's water supply come from groundwater. The quality of this groundwater is at risk if high concentrations of nutrients such as nitrate and phosphate are leached from the soils in the catchment area.

The benefits of soil amendment materials to increase nutrient retention and water-holding capacity have been recognised, and are widely used in the Perth metropolitan area. However, most of these soil amendment materials consist of blends of organic materials such as composted green waste, treated sewage, animal manures and sawdust. These blends are valuable in that they supply a "slow-release" form of nutrients such as nitrogen and phosphorus and also increase water holding capacity and retention of cationic nutrients such as potassium and trace elements. However, they are not able to adsorb soluble anionic nutrients such as phosphate. Indeed, large amounts of organic matter can actually inhibit the adsorption of these nutrients by the soil particles. In many cases, leached phosphate is responsible for the nutrient enrichment of the local groundwater, lakes and rivers.

Another problem caused by use of large amounts of these organic soil amendments on sandy soils is that they often cause the soils to become hydrophobic (“water repellent” or “non-wetting”). As a result, water use becomes very uneven and ineffective. This condition is largely controlled by the use of synthetic wetting agents (non-ionic detergents). However, it is yet to be proven that widespread use of these agents does not cause adverse environmental effects.

Although the philosophy of using soil amendment materials, particularly those produced by recycling green waste and animal manures is fundamentally sound, it does not solve the problem of phosphate leaching in the long term. Indeed, it may well accelerate the process by blocking soil adsorption sites.

Research conducted by the Chemistry Centre and Agriculture Western Australia in the 1980’s and 1990’s has shown that the poor adsorption of phosphate by sandy soils of the coastal plain is caused by a lack of iron/aluminium oxide minerals. It is possible to provide these minerals by amending the sandy soils with clays and loams that are naturally high in these minerals, or by using wastes from mineral extraction industries such as bauxite processing waste or “red mud”. Additions of relatively small amounts of these materials greatly enhance the phosphate adsorption capacity of the soils (from <20% retention to >80% retention). Use of these materials also confers additional benefits such as:

- Countering soil acidity
- Improving water-holding capacity and water use efficiency
- Countering soil hydrophobicity
- Increasing retention of soil organic matter

(The latter point has additional significance in that it provides a soil sink for atmospheric carbon dioxide, which is believed to be responsible for global warming. Under the Kyoto Agreement of 1991, Australia may be able to claim “Carbon Credits” for the amount of increased soil carbon.).

1.2 Project Aims

1. To investigate the extent of over fertilisation of soils in the urban regions of the Swan Coastal Plain.
2. To determine the effectiveness of commercial landscaping blends or soil amendment materials for preventing nutrients, particularly phosphorus, from leaching into the groundwater.
3. To identify local soils or waste materials that could be incorporated into landscaping blends to improve nutrient retention and counter soil hydrophobicity.

This report presents the results of a preliminary investigation using limited Chemistry Centre resources directed towards the first project aim. The results from this investigation will be used to develop project proposals directed towards other funding sources such as other State and Commonwealth Government Departments.

2. METHODOLOGY

2.1 Collection of Samples

Samples of soil were provided by eleven staff members from the Chemistry Centre. Each participant was also asked to provide additional information on their land management techniques by completing a questionnaire (Appendix 1). The questionnaire provided information on the age of the properties, types and rates of fertilisers used, extent of use of soil amendments such as composts and loams, and use of other materials such as soil wetting agents. Soil samples were also collected from nearby undeveloped blocks and low-maintenance council parks to provide a baseline for nutrient levels and soil properties before urban development commenced. The collection of samples analysed represent different levels of nutrient input and soil management and include areas of turf, native gardens, exotic gardens and vegetable / fruit tree patches.

Despite the limited number of participants due to funding restrictions, the collection of samples provided a reasonable coverage of the urban areas of the coastal plain, although the poorest sandy soils from the Jandakot, Canning Vale, Ballajura and Bassendean areas are not well represented (Figure 1).

2.2 Sample Preparation

Most of the soil samples were collected using a commercial soil sampling tool that is designed to collect samples of the top 10 centimetres of soil. Some participants used a small spade to collect samples from small garden beds. Separate samples (up to 5 per participant) were collected from distinct areas of each household such as lawn areas, garden beds, native gardens and vegetable patches. Each sample consisted of 20 to 30 individual cores, which were mixed thoroughly in a plastic bucket. A subsample weighing 500 g to 1 kg was submitted to the laboratory.

Descriptions of the samples submitted are listed in Appendix 2.

Each sample was dried in a fan forced drying oven (40°C), then sieved through a 2 mm screen to remove gravel and coarse organic material, such as thatch from lawn areas. A sub-sample of each sieved sample was finely ground in a ring-grinding mill in preparation for organic carbon analyses.

The samples were analysed for electrical conductivity (EC) of a 1:5 soil:water extract using a calibrated Conductivity meter with temperature compensation to report EC values at 25°C. Soil pH of a 1:5 extract of soil with 0.01 M calcium chloride was measured using a pH meter with a combination calomel-glass electrode.

2.3 *Methods of Analysis*

Particle size distribution was determined by a sedimentation technique using a plummet balance after dispersing the soil with a solution of sodium hydroxide and sodium hexametaphosphate (Calgon) (Australian Standard AS 1289.C6.2). The density of the silt and clay particles was assumed to be 2.6 g/cm^3. Clay particles were deemed to have diameters less than 0.002 mm. Silt particles were defined as particles having diameters between 0.02 and 0.002 mm.

Figure 1. Location of sampling sites from urban areas of the Swan coastal plain.

Organic carbon was determined by a wet oxidation technique using finely ground subsamples of soil. The procedure used was a modification of the Walkley and Black

(Walkley and Black, 1934) procedure using spectrophotometric determination of the chromium (III) ions produced by oxidation of soil organic matter.

Available phosphorus was determined with a Segmented Flow AutoAnalyser using the method of Colwell (1963). The method measures inorganic phosphate extracted from soil using 0.5 M sodium bicarbonate (pH 8.5) under controlled conditions (1:100 soil:solution, end-over end extraction at 10 rpm, 23°C). Extractable potassium in the extract was measured by flame atomic absorption spectrophotometry (AAS) (Rayment and Higginson, 1992).

Phosphorus adsorption capacity was measured by a ‘single point’ adsorption technique developed by the Chemistry Centre (Allen and Jeffery, 1991). In this test, soil (5 g) is equilibrated with a solution initially containing 10 mg P/L as potassium dihydrogen orthophosphate (KH_2PO_4) in 0.02 M potassium chloride with 0.25% v/v of chloroform added as an inhibitor against microbial activity. Equilibration is achieved by shaking at 10 rpm for 16 hours at 23°C using end-over-end shaking. The concentration of P (P_{eq}) in the clarified solution is measured using the method of Murphy and Riley (1962). The Phosphorus Retention Index of the sample is calculated as the ratio P_{ads}/P_{eq} where P_{ads} is the amount of P (mg P/kg) adsorbed by the soil during the extraction period.

The tendency for the soils to become hydrophobic (water-repellent) was quantified by using the Molarity Ethanol Droplet (MED) test of King (1981). The test measures the minimum concentration of a droplet of aqueous ethanol that wets the soil in less than 20 seconds.

The complete set of results from the analysis of the soils is listed in Appendix 3.

3. RESULTS AND DISCUSSION

3.1 Particle Size Distribution

With very few exceptions, the samples analysed were extremely sandy, as shown by the textural diagram, Figure 2. The distribution of silt and clay contents indicates that only one sample had a clay content higher than 5% (Figure 3). This sample was amended many years ago by incorporation of several tonnes of loam.

The soils with the highest sand contents were from Mt Claremont, Ellenbrook, Morley, Riverton and Waterford. Only one of the 19 soils from these suburbs had a sand content of less than 98%. With the exception of Mt Claremont, these suburbs are located more than 10 km from the coast. This observation is consistent with the generally accepted theory for the evolution of sandy soils on the Swan Coastal Plain. The sandy soils occur as a series of sand dune of increasing age with distance from the coast (McArthur and Bettenay, 1960). The youngest dunes belong to the Quindalup series, which were not sampled in this investigation. Samples from Duncraig, Marmion, Spearwood, Mt Claremont are from the older Spearwood dune formations, while the remaining samples are mostly composed of soils from the oldest dune system (Bassendean) of the coastal plain.

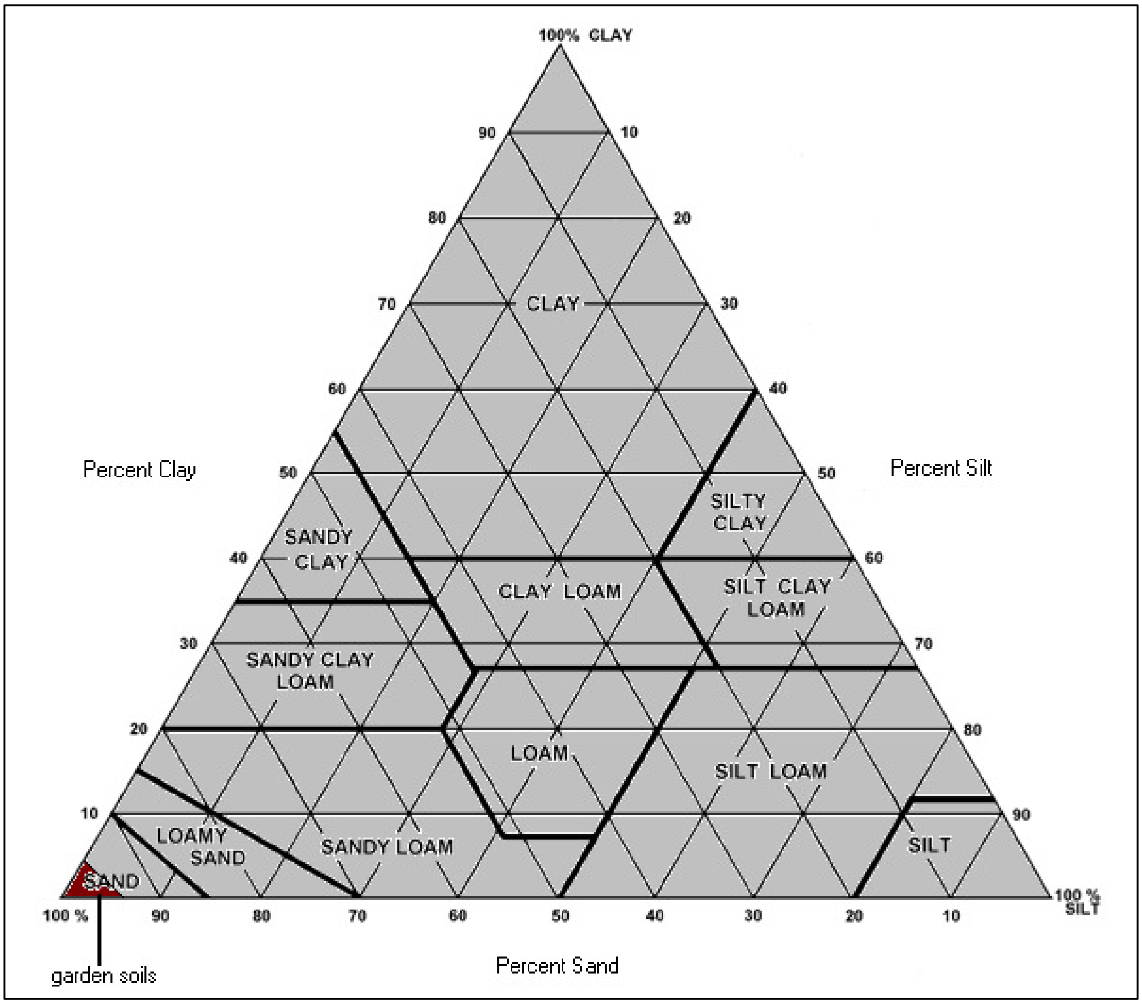
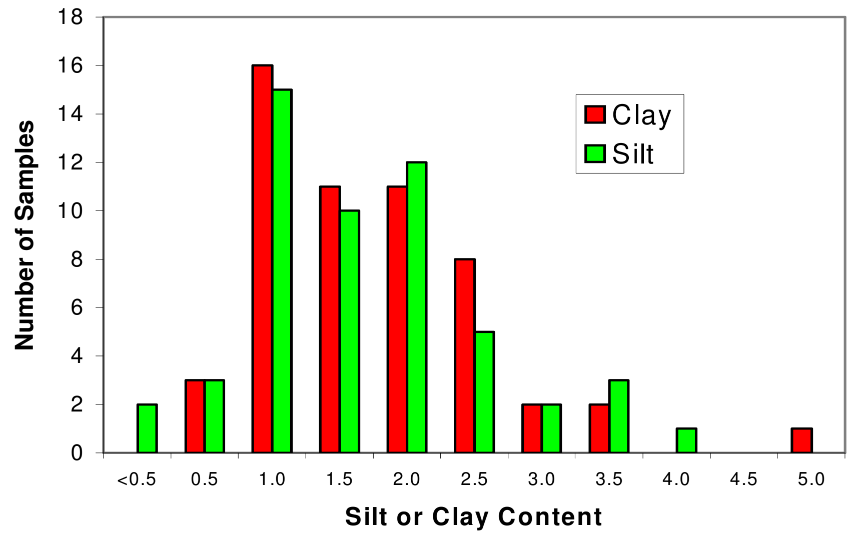


Figure 1. Soil texture diagram indicating the extreme sandy texture of soils from Perth urban gardens.

The distribution of silt contents was similar to clay contents, and there was a reasonable correlation between them (*r* = 0.69). The sand particles consisted mainly of quartz granules. All samples were coloured grey, the intensity increasing with increasing organic matter content.

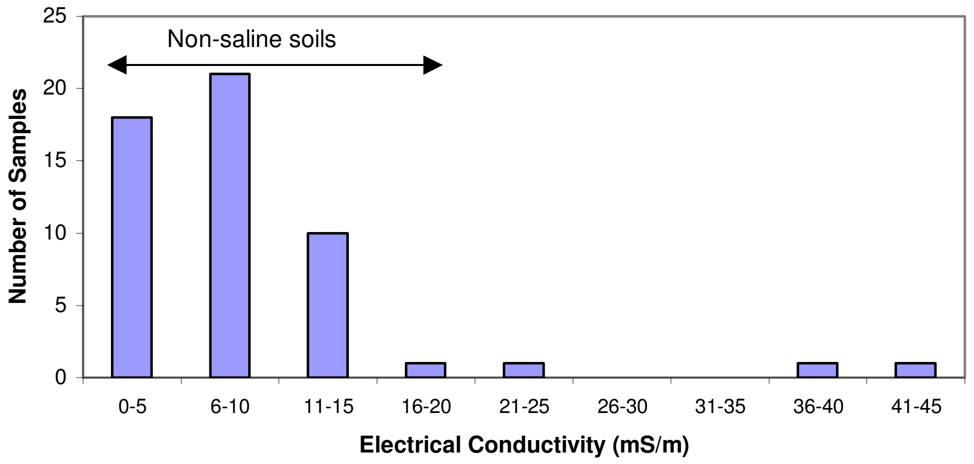
Figure 3. Distribution of Silt and Clay Contents.



3.2 *Electrical Conductivity (Salinity)*

With very few exceptions, the electrical conductivity values of water extracts indicated that the soils were non-saline (Figure 4). Electrical conductivity values of <20 mS/m indicate non-saline soils. All of the samples with EC values >20 mS/m had very high levels of extractable nutrients (P and K), suggesting that they had been recently fertilised.

Figure 4. Distribution of Electrical Conductivity Values



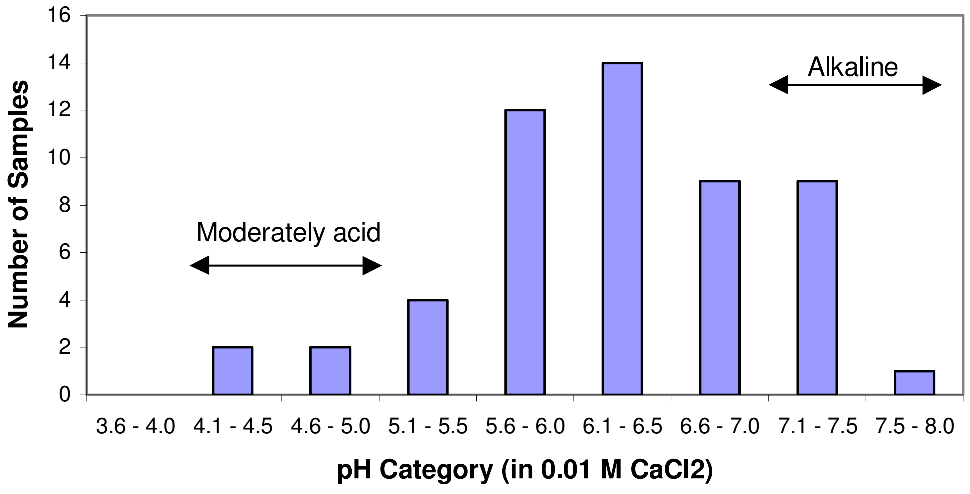
3.3 *Soil Acidity -pH*

Acidic soils are widely distributed throughout Western Australia (Porter, 1984). Apart from a thin belt of alkaline calcareous soils along the coast, most of the sandy soils of the coastal plain are naturally acidic, as a result of many thousands of years of weathering. Land management practices such as inefficient use of nitrogen fertilisers and intense leaching will lead to further soil acidification. However, the survey indicated that most of the soils did not suffer from severe acidification (Figure 5).

Most of the soils tested can be classed as neutral or weakly acidic. Two of the soils rated as moderately acidic were collected from a residence in Daglish that has been fertilised for more than 60 years.

The soils rated as alkaline were collected from properties in Karrinyup and Nedlands. Both properties were reticulated from a bore. The alkalinity of the water is likely to be responsible for the soil alkalinity at these sites.

Figure 5. Distribution of Soil pH Results

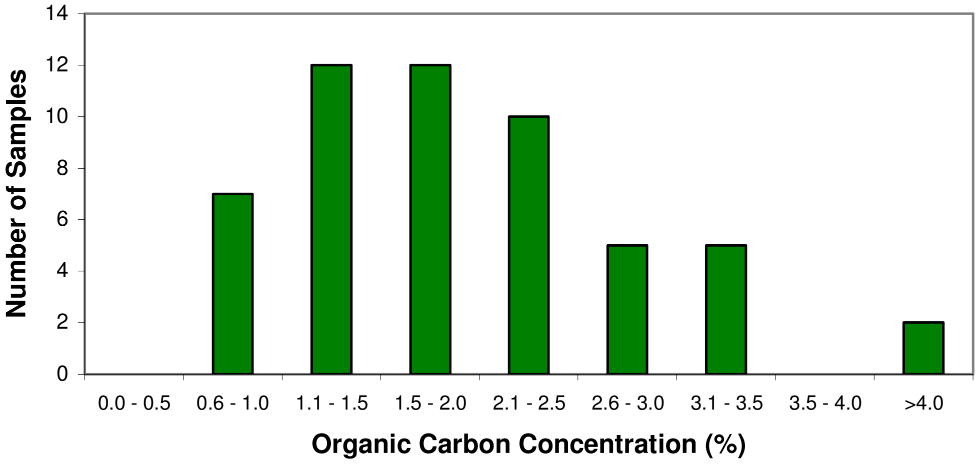


3.4 *Organic Carbon*

Samples of soil collected from bush reserves that had received little or no soil amendment materials or fertiliser had low levels of organic carbon, typically less than 1% (Figure 6). Much higher levels of organic carbon were found in garden soils, particularly those that are treated with composts, manures and recycled garden waste. Soils under turf generally had intermediate levels of carbon.

These results indicate that the soils have a high capacity to assimilate soil organic carbon, despite anecdotal observations that organic matter breaks down rapidly in sandy soils under the climatic conditions experienced in the temperate southwest of WA. Approximately 30 tonnes of organic matter per hectare are required to increase the organic carbon content of the top 10 centimetres of soil by 1% (as soil carbon).

Figure 6. Distribution of Organic Carbon Values.



This accumulated organic matter represents a valuable soil resource, as it supplies ‘slow-release’ nutrients including nitrogen, sulphur and phosphorus, it can adsorb cationic nutrients such as calcium, magnesium, copper, iron and zinc, it improves soil structure and increases water holding capacity.

3.5 Available Phosphorus

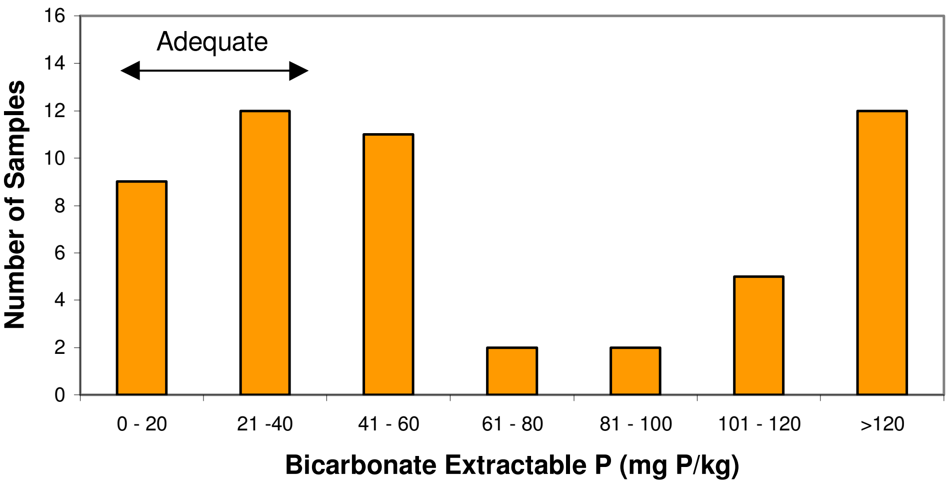
In their native state, the sandy soils of the coastal plain, contain very low levels of phosphorus. Much of the native vegetation consists of plants that either have a very low requirement for phosphorus, or have developed root systems that are extremely effective at scavenging phosphorus from the soil.

Agriculture in Western Australia developed rapidly during the twentieth century when it was realised that they responded dramatically to the addition of phosphatic fertilisers. Addition of phosphorus in soluble fertilisers such as superphosphate lead to a dramatic expansion of both horticulture on the coastal soils in the higher rainfall areas of the southwest of Western Australia and production of grain crops in the drier regions east of the Darling Scarp.

However, repetitive application of soluble phosphatic fertilisers on the sandy soils of the agricultural areas on the Swan coastal plain, the catchment area of the Peel-Harvey estuaries and the sandy areas of the south coast (Walpole to Esperance) has lead to eutrophication of coastal rivers, lakes and estuaries as a result of leaching of phosphates from the sandy soils by the relatively high rainfall. A survey of the farms in the Peel-Harvey catchment area (Yeates *et al.,* 1984) indicated that a high proportion of these soils analysed contained more phosphorus, as measured by the Colwell bicarbonate extraction test, than was required for optimal plant production. Analysis of the samples of soil from the current investigation indicated that many soils contained excessive amounts of plant available phosphorus, more so than the farm soils from the Peel-Harvey catchment area. The amount of extractable phosphorus required for healthy lawns on sandy soils is 20 to 25 mg/kg. Vegetable crops and annual plants may require higher levels of phosphorus, up to 50 to 60 mg P/kg. Native plants can grow quite satisfactorily with as little as 2 to 5 mg P/kg. The bush reserve areas contained 2 to 10 mg P/kg.

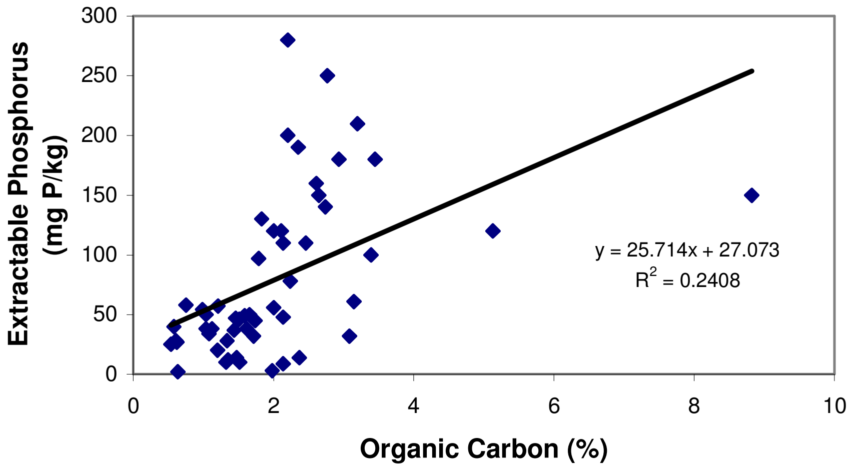
It is clear from the distribution of extractable phosphorus levels in Figure 7 that many of the soils contain much more phosphorus than is required for healthy plant production. As the native soils contain very little phosphorus, most of the stored soil P was derived from inputs such as organic and inorganic fertilisers and organic soil amendment materials. Treated sewage waste ('biosolids') is widely used in commercial soil amendment materials. These materials contain high levels of labile phosphorus.

Figure 7. Distribution of Extractable Phosphate Results



The amount of extractable phosphorus is positively correlated (r^2 = 0.24) with the amount of organic carbon present in the soil (Figure 8), but not with the silt or clay contents. This result indicates that organic matter added to the soil provides a significant source of available phosphorus. However, inorganic fertilisers also supply a significant amount of available phosphorus, as indicated by the high soil test results for samples from Karrinyup and Marmion where these fertilisers were frequently used.

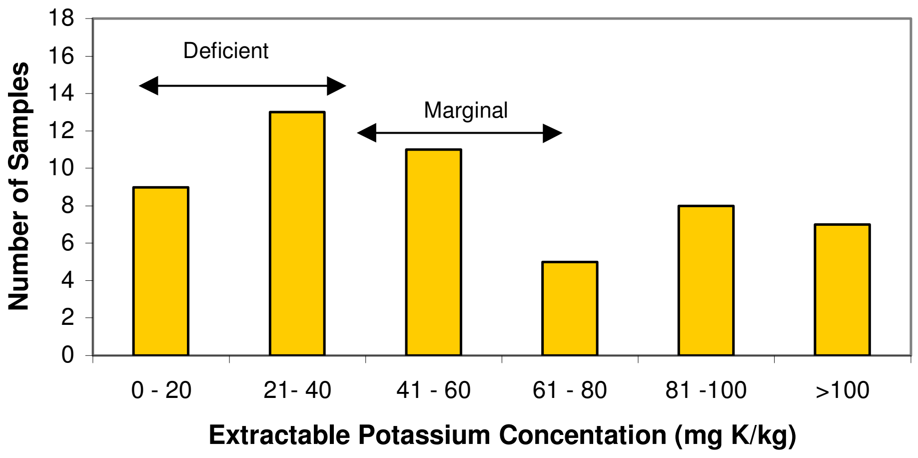
Figure 8. Comparison of Organic Carbon and Extractable Phosphorus Concentrations in Urban Soils.



3.6 Available Potassium

Sandy soils are often deficient in potassium, another essential element for plant production. A survey of the soils from the Peel-Harvey catchment indicated that many of the agricultural soils were deficient in potassium, as this element was rarely included in fertiliser formulations used on these soils until recently (unpublished data, Chemistry Centre (WA)). A similar observation was observed with the collection of urban soils (Figure 9).

Figure 9. Distribution of Extractable Potassium Concentrations in Urban Soils.



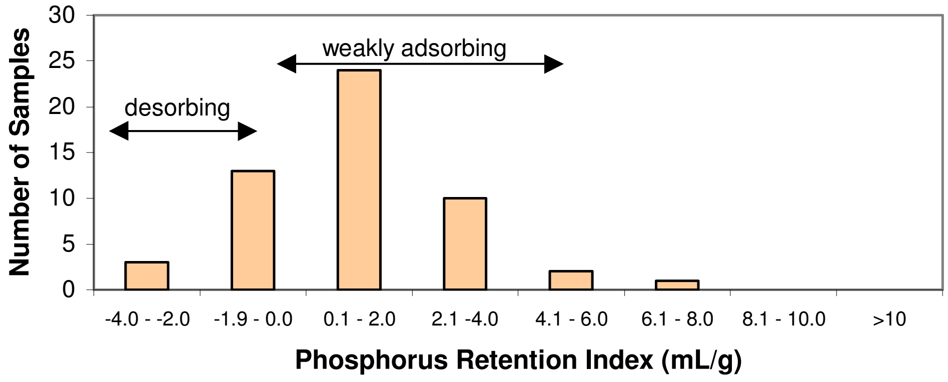
Many soils in the survey contained marginal or deficient levels of extractable potassium. Extractable potassium was positively correlated with organic matter content ($r^2 = 0.45$), silt content ($r^2 = 0.33$) and, to a lesser degree, clay content ($r^2 = 0.12$). These results indicate that the increase in extractable K (native soils generally contained very little potassium) was mainly caused by inputs of organic matter, balanced fertilisers and also loam soil amendments. Many commercially available organic fertilisers such as composts, particularly those containing 'biosolids', and animal manures are generally well supplied with phosphorus and nitrogen, but often contain much lower concentrations of potassium.

3.7 Phosphorus Retention

The Phosphorus Retention Index was developed by the Chemistry Centre (Allen and Jeffery, 1991) to provide a quantitative measure of the ability of soil to adsorb (or desorb) phosphorus. Most soils throughout the world have very high capacities to adsorb soluble P from solution, as the P is strongly bound to mineral surfaces of hydrous iron and aluminium oxides, clays and calcium carbonate (limestone). However, the results of this investigation indicate that all samples analysed for this investigation have very low phosphate adsorption capacities (Figure 10).

The results indicate that approximately 30% of the soils tested were either desorbing or had no P adsorption capacity, which indicates that the topsoil had become saturated with phosphorus. Any additional soluble forms of P added to these soils will be leached beyond the topsoil following heavy rainfall events or excessive irrigation.

Figure 10. Distribution of PRI Values of Urban Soils.



Several Shire Councils in rural areas of Western Australia have implemented strict controls for installation of domestic leach drains to prevent nutrient leaching into waterways. In many cases, a minimum soil PRI value of 20 mL/g is required by the Shires to prevent leaching of soluble P from domestic effluent. Soils suitable for medium input agriculture on the coastal plain should have PRI values of 5 mL/g or more to prevent significant leaching losses of P from fertiliser applications. Only 2% of the soils studied in this investigation fit into this category.

There were weak positive correlations between PRI and clay content (r = 0.35) and soil pH (r = 0.38). PRI was negatively correlated with organic matter content (r = -0.27) and bicarbonate-extractable phosphorus (r = -0.05). These results suggest that the alkalinity of some soils could have increased the P sorption capacity of soil, while addition of organic matter tend to reduce P sorption capacity. Soils with higher clay contents tend to have higher P sorption capacities.

As most of the commercially available soil blends have high organic matter contents and low clay content, the use of these materials for soil improvement has effectively reduced the P sorption capacity of many garden soils to levels that are likely to result in leaching of significant amounts of phosphorus from the topsoil.

3.8 Soil Hydrophobicity

Sandy soils containing elevated amounts of organic matter from decomposing plant debris often become hydrophobic or ‘non-wetting’ due to the presence of organic waxes that can coat the soil particles. Figure 11 indicates that a significant number of soils in this investigation have become hydrophobic (none of the native soils tested were hydrophobic), according to the rating scale proposed by King (1981).

Figure 11. Distribution of MED Values

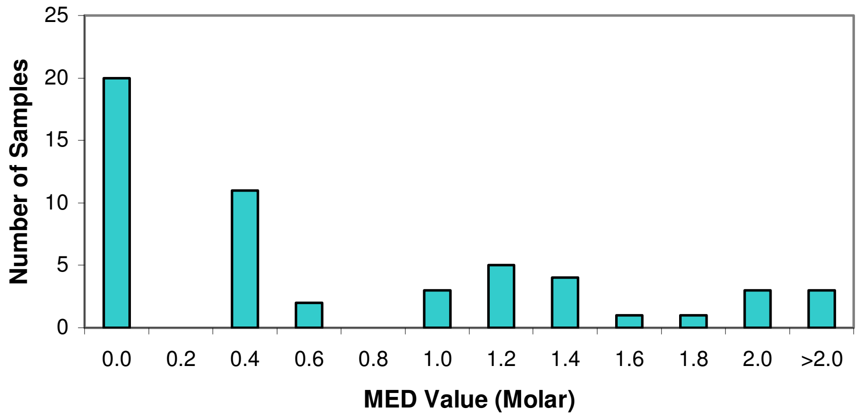


Table 1. *Rating of soil hydrophobicity as rated by the Molar Ethanol Droplet (MED) test (after King, 1981).*

MED value (M)	Hydrophobicity Rating
0.0	very low to low
0.0 to 1.0	low

1.2 to 2.2	moderate
2.4 to 3.0	severe
>3.2	very severe

The degree of hydrophobicity as measured by the Molarity Ethanol Droplet test is highly correlated (r = 0.57) with the organic matter content of the soil (Figure 12). It is also strongly, but negatively correlated with the Phosphorus Retention Index (r = -0.38) and clay content (r = -0.44).

Work conducted by Agriculture Western Australia has shown that clay addition to sandy hydrophobic soils can greatly improve crop production through increased germination rates and water use efficiency (Carter *et al*., 1998). Amended soils with clay contents greater than 5% were generally not hydrophobic, and were able to increase grain yields by up to 200%.

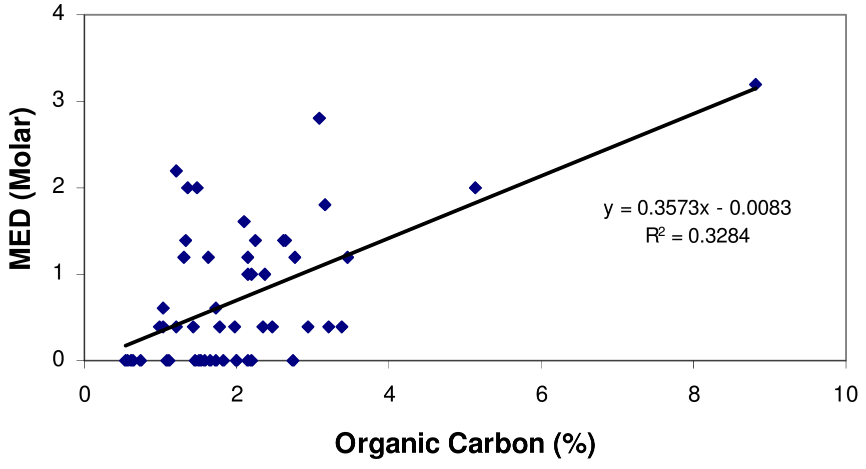


Figure 12. Relationship Between MED Test Values and Organic Carbon Content.

3.9 *Assessment of Effectiveness of Current Management Practices*

The results of this investigation indicate that current management practices of soils in residential gardens in the Perth metropolitan area, based on widespread use of organic fertilisers and soil amendment materials, in conjunction with varying use of inorganic fertilisers, have resulted in considerable increases in the organic matter and available phosphorus levels of soil. Potassium levels have also increased, but many soils remain in a deficient or marginal condition with respect to potassium supply.

These practices have also caused a dramatic decrease in the phosphate adsorption capacity to a point where 30% of soils tested have exhausted their capacity to retain soluble P. A significant proportion of soils has also developed hydrophobic characteristics, and may require regular applications of soil wetting agents to increase water use efficiency.

Soil pH does not appear to have been significantly affected by the use of soil amendment materials or fertilisers. It is likely that soil acidity may develop with time, or the effect of these practices may have resulted in acidification of the subsoils, which were not tested in this investigation.[1]

Very few households have used clay soil amendments. Those that have applied loams to increase the clay content have generally produced soils with higher potassium levels, increased P sorption and have produced less hydrophobic soils.

3.10 Analysis of Commercial Landscaping Soil Blends

Soil blends for landscaping and soil improvement purposes are available from a number of companies in the Perth metropolitan area. Most of these soil blends contain a high content of organic matter, mainly from composted green waste, ‘biosolids’, animal manures and waste materials from industrial processes such as brewery or mushroom residues.

As part of this investigation, eight samples of commercial landscaping soil blends were collected and analysed for nutrient content, clay content and nutrient retention properties. A description of each sample is listed in Table 2.

Table 2. *Description of commercial soil blend samples.*

Lab No	Sample	Description
00A		
62_001	Lawn mix	Yellow sand, Gingin loam, poultry manure
62_002	Landscape mix	Screened sand, sedge peat, ‘biosolids’, sawdust
62_003	General mix	Gingin loam, sedge peat, ‘biosolids’, sawdust
62_004	Vegetable mix	Screened sand, karri bark, poultry manure, ‘biosolids’
62_005	Native mix	Yellow sand, Gingin loam, sedge peat, ‘biosolids’
62_006	Azalea mix	Pine bark, karri bark, sawdust, sand, sedge peat, ‘biosolids’
62_007	Rose mix	Gingin loam, cow manure, sawdust, sedge peat
62_008	Annuals mix	Customised soil blend

The samples were prepared by the same method used for preparation of the garden soils. Most of the samples contained a large proportion of coarse organic matter. After sieving, the weight of >2 mm material was recorded and calculated as a percentage of the dried sample. With the exception of the MED test, the <2 mm

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[1] Subsoil acidification is commonly observed in agricultural soils of the high rainfall and cereal growing areas of the southwest of WA.

fraction was analysed for the same suite of analytes as for the garden samples. Total nitrogen and phosphorus concentrations were also measured following digestion of finely ground sub-samples with a sulphuric acid – potassium sulphate - copper sulphate mixture. Ammonium-N and phosphate-P in the diluted digest solution were measured by segmented flow auto-analysis and UV-visible spectrometry, respectively.

The results for the analysis of the landscaping blends are listed in Appendix 4.

Not surprisingly, the results for the analysis of the commercial soil blends were similar to those of the garden soils. Likely reasons for this include the use of landscape mixes by several householders, and the widespread use of animal manures, composts and recycled garden waste as fertilisers for garden soils. The clay contents of the commercial blends were slightly higher than those of the garden soils, due to the incorporation of a loamy sand material ("Gingin loam"). With the exceptions of blends for lawn topdressing and native garden mixes, organic carbon levels in the soil fraction were generally higher than those of the garden soils. pH values were close to neutral. The lowest values were observed for the azalea and rose mixes due to addition of ferrous sulphate. However, lower values would be more desirable for these plant species.

Total nitrogen concentrations in the soil fraction were relatively low, considering the high organic carbon concentrations. On the other hand, total phosphorus concentrations were very high. A considerable proportion of the total phosphorus is present in a plant-available form, as indicated by the relatively high results for extractable P (sodium bicarbonate extract). The potassium concentrations of several blends are rated as fairly low, particularly when compared to the nitrogen and phosphorus contents.

With the exceptions of the native soil mix and the rose mix, the blended soils have very low phosphate adsorption capacities. Two soils were completely saturated with P, as indicated by the negative values for the Phosphate Retention Index (PRI). These soils had the highest concentrations of total phosphorus (1400 mg P/kg).

The presence of 'biosolids' is believed to be responsible for the high phosphorus content and low P adsorption capacities of the blended soils. The soil with the highest P adsorption capacity, the rose mix (sample 7), contains no 'biosolids'. The native garden mix, which has a relatively high PRI value (6.1 mL/g) contains only a small amount of 'biosolids'.

These results indicate that the commercial blends are useful soil amendment/soil replacement materials in terms of their relatively high organic matter and nutrient contents and neutral pH values. The macronutrient ratios are somewhat unbalanced in that P:N and P:K ratios tend to be higher than optimal. The low clay contents ensure that the soils will drain freely, but they may cause amended soils to become hydrophobic, particularly when mixed with very sandy natural soils of the Swan coastal plain. The main disadvantage of these soil blends as ameliorants for leaching sands is the lack of any components with a high capacity for retaining phosphorus. This limited P adsorption capacity, in combination with the high concentrations of total P in a readily available form, indicates that these soils may lose significant amounts of phosphate by leaching when added to soils with low PRI values.

3.11 Recommendations for Further Work

Despite the limited number of samples processed as part of this investigation, there is evidence that current practices used for improvement of sandy soils in urban domestic gardens have lead to significant improvements in soil fertility, as indicated by increased organic matter and nutrient (P and K) contents. There does, however, appear to be a nutrient imbalance in some of the products used to improve sandy soils in that many soils contain excessive amounts of phosphorus, but marginal or deficient amounts of potassium. This was attributed to the widespread use of composts, animal manures and landscaping soil blends based on composted green waste and 'biosolids'. The amounts of accumulated soil nitrogen were not considered in this investigation. Neither were other essential elements such as calcium, magnesium, sulphur and trace elements (boron, copper, manganese, iron and zinc).

Many soils have very low, or negligible capacities to retain soluble phosphates. Application of soluble fertilisers is likely to result in leaching of phosphorus (and nitrogen) from the topsoil, and potentially into coastal lakes, rivers or groundwater. The poor phosphate adsorption capacity of these soils is attributed to the lack of clay minerals, particularly those rich in hydrous aluminium and iron oxides.

If current practices are maintained, movement of nutrients such as phosphorus and nitrogen through the soil profile is inevitable, unless the subsoil can retain these nutrients through P sorption processes. The deep yellow sands of the Spearwood system have a reasonable capacity to retain soluble P. However, because the application rates of nutrients to improved garden beds are very much higher than those used in agricultural systems, it is likely that preferred pathways for nutrient flow to the groundwater will eventually form.

Earlier work conducted by the Chemistry Centre and Agriculture Western Australia (Robertson *et al.,* 1999) has shown that certain natural clay soils and industrial by-products such as bauxite mining residue and neutralised acid effluent from the alumina and mineral sand processing industries, respectively, have very high capacities to retain phosphorus and other nutrients. In addition, they can confer other useful soil properties such as increasing water holding capacity and overcoming soil hydrophobicity. Addition of these materials to the current landscaping supplies will greatly improve their soil amendment capabilities for the sandy soils of the coastal plain.

To facilitate improvement of soil landscaping materials and their widespread adoption by urban householders, local councils and other land managers, further research should be directed towards the following activities:

- A wider survey of domestic gardens and local council reserves to cover a more representative sample of the Perth Metropolitan area. The analyses should also cover a wider range of nutrients, including nitrogen, sulphur, major soil cations and trace elements. Samples of subsoils should also be analysed to determine the extent of nutrient movement through the subsoil.

- New blends of landscaping materials containing either natural clays or highly P-fixing industrial by-products should be evaluated as soil amendments through controlled laboratory and field experiments. These experiments are required to determine optimum blend ratios, and provide demonstration plots for local councils.
- A major educational campaign should also be undertaken to provide information to residents and other land mangers of the coastal plain to better manage nutrients on sandy soils.

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APPENDIX 1

GARDEN USE QUESTIONNAIRE SUPPLIED TO PARTICIPANTS
MANAGING NUTRIENTS IN URBAN DOMESTIC SOILS

Thank you for offering to participate in this Chemistry Centre project, which will help us develop new products and techniques for better management of nutrients in domestic gardens on the sandy soils in the Perth metropolitan area.

As most Perth gardeners know, the sandy soils of the coastal plain can only be used to grow the hardiest of native plants unless the soils are improved by the addition of fertilisers and soil amendment materials. A wide range of fertilisers are available for supplying nutrients to plants, including granulated inorganic materials, slow release fertilisers, composts, animal manures and other waste materials. Amendment materials are generally used to improve the water holding capacity and nutrient retention and most are based on organic materials such as composts, manures and peat products.

Apart from poor nutrient retention and low water holding capacity, sandy soils often become hydrophobic or ‘non-wetting’ during the dry summer period. This condition can be managed by regular applications of commercial wetting agents, which will improve water infiltration and significantly reduce the cost of watering.

The aim of this project is to determine the effect of the various soil amendments and nutrient management practices on various soil chemical and physical properties. From this information, the Chemistry Centre will work with the various commercial landscape material suppliers and other Government agencies to develop improved products. These products will provide benefits to the landowner and environment by saving water and fertiliser costs, and reducing runoff of excess nutrients into our lakes and rivers.

To participate in the project, we ask you to complete the attached questionnaire and provide the Land Resources Section with samples of your soil. In return, you will be provided with the results of analysis of your soils and an assessment of the general condition and any problems associated with your soil.

Your soil samples will be analysed for the following:

pH (soil acidity/alkalinity)
Electrical conductivity (salt content)
Organic carbon
Available phosphorus and potassium
Phosphorus Retention Index
Sand, silt and clay content
MED (non-wetting properties)

COLLECTING SOIL SAMPLES

To test your soil, we require approximately 500 – 1000 grams of a representative sample from each of the different sections of your garden. A maximum of 5 samples per family is permitted. Try to collect several samples from different areas such as your lawn, high and low maintenance garden areas, and if possible, for your local park or bushland reserve.

To collect your soil samples, you will require the following items:

- A sampling tool to sample the top 10 centimetres of soil. A soil sampler or 'pogo' can be borrowed from the Land Resources Section. Otherwise, you can use a piece of clean PVC reticulation pipe that has a graduation mark at 10 cm.
- A clean plastic bucket.
- A permanent marking pen.
- Plastic sample bags (or a clean jar or ice cream container)

To collect the samples, follow the following steps.

- Remove any surface litter or mulch layers to expose the soil surface.
- Push the sampling tool or plastic tube into the top 10 cm of soil.
- Tilt the tool to a 45°angle, then carefully remove the tool from the soil, taking care not to spill any of the sample.
- Place the core of soil into the clean plastic bucket.
- Collect a minimum of 10 –15 such cores from the sampling area.
- Gently break up the cores and mix the sample in the bucket.
- Remove several handfuls from the sample into the sample bag. It is not necessary to remove any coarse organic matter or stones, as these will be removed by sieving in the laboratory prior to analysis.
- Label the sample bag using the permanent mark and complete the details on the appropriate sample submission sheet (one sheet for each sample).
- Bring the samples to the laboratory, together with the completed questionnaire and sample submission sheets on the following day.

It is not necessary to dry the sample or take special precautions to keep the sample cool, other than protecting it from direct sunlight after the sample has been taken.

LAND USE QUESTIONNAIRE

Please provide brief answers to the following questions to provide us with additional information to facilitate interpretation of the soil test results.

Surname ______________________________

Suburb ______________________________

Age of residence/block (if known) __________ years

Number of years that you have lived here __________ years

Please provide an estimate of the area (in square metres) devoted to the following:

High maintenance lawn (regular fertilising and mowing ________ m^2

Low maintenance lawn (i.e. generally neglected) ________ m^2

Bedding plants/vegetable patches ________ m^2

Exotic scrubs, palms, ferns scrubs etc ________ m^2

Native plants ________ m^2

Use of soil amendment materials:

Please indicate to the best of your knowledge if the following soil amendment materials have been used and relative amounts:

Material	**Application rates**			
	High	**Moderate**	**Low**	**Nil**
Peat/composts	☐	☐	☐	☐
Landscaping soil blends	☐	☐	☐	☐
Animal manures	☐	☐	☐	☐
Topdressing sands	☐	☐	☐	☐
Loams or clays	☐	☐	☐	☐

Description of application rates:
High = truckloads (tonnes)
Moderate = trailer loads (approx. 1 tonne)
Low = bags (20 –50 Litres)

Use of fertilisers:

Please indicate which of the following fertilisers you use on a regular basis, and at what application rates.

Manures, composts	☐	High:	trailer loads each year
	☐	Moderate:	several bags per year
	☐	Low:	one bag every year or two
Granulated mineral fertilisers	☐	High:	several bags (20 kg) each year
	☐	Moderate:	one bag (20 kg) per year
	☐	Low:	one bag every 2 or 3 years
Liquid fertilisers	☐	High:	several litres per year
	☐	Moderate:	one or two litres per year
	☐	Low:	one litre every 2 or 3 years

CHEMISTRY CENTRE DOMESTIC URBAN SOILS PROJECT

SAMPLE SUBMISSION SHEET

Name: ____________________________________

Indicate with a ‘X’ from which area each sample was collected

Sample Number	*1*	*2*	*3*	*4*	*5*
High maintenance lawn	☐	☐	☐	☐	☐
Low maintenance lawn	☐	☐	☐	☐	☐
Bedding plants section	☐	☐	☐	☐	☐
Vegetable garden	☐	☐	☐	☐	☐
Exotic garden (ferns/palms/scrubs)	☐	☐	☐	☐	☐
Native garden	☐	☐	☐	☐	☐
Local bush/park	☐	☐	☐	☐	☐

What types of fertilisers and soil amendments have been used in this section of the garden?

Compost	☐	☐	☐	☐	☐
Peat, sawdust	☐	☐	☐	☐	☐
Manures	☐	☐	☐	☐	☐
Natural loams	☐	☐	☐	☐	☐
Landscaping blends	☐	☐	☐	☐	☐
Granulated fertilisers	☐	☐	☐	☐	☐
Liquid fertilisers	☐	☐	☐	☐	☐
“Slow-release” fertilisers	☐	☐	☐	☐	☐
Agricultural lime	☐	☐	☐	☐	☐
Topdressing sand	☐	☐	☐	☐	☐

When was the last time this area was fertilised?

Less than one month	☐	☐	☐	☐	☐
1 to 3 months	☐	☐	☐	☐	☐
3 to 6 months	☐	☐	☐	☐	☐
6 to 12 months	☐	☐	☐	☐	☐
1 to 3 years	☐	☐	☐	☐	☐
can’t remember	☐	☐	☐	☐	☐

APPENDIX 2

Sample Descriptions

Lab No 99A	Identification	Description
950_001	Daglish 1	High maintenance turf, has been amended with loam, topdressing sand and lime
950_002	Daglish 2	Low maintenance turf, no loam, fertilised
950_003	Daglish 3	Exotic garden, mulched with garden waste, annual fertiliser applications
950_004	Daglish 4	Vegetable garden, heavy applications of garden waste, especially lawn clippings
950_005	Daglish 5	Railway reserve
950_006	Duncraig 1	High maintenance turf, some soil organic amendment, high inorganic fertiliser use
950_007	Duncraig 2	Garden beds, soil amended with organic matter and loam, high inorganic fertiliser use
950_008	Duncraig 3	Palms and scrubs, soil amended with organic matter, moderate inorganic fertiliser use
950_009	Duncraig 4	Native garden area, minor amendment with organic matter, low fertiliser use
950_010	Duncraig 5	Bush area
950_011	Marmion 1	High maintenance turf, improved with loams, organic blends, recently fertilised
950_012	Marmion 2	Bedding plants section, no loam, composts and manures also used
950_013	Marmion 3	Exotic garden beds, as for Marmion 2
950_014	Marmion 4	Exotic garden beds, as for Marmion 3 but without composts
950_015	Marmion 5	Bedding plants, not improved, manures and granulated fertilisers used
950_016	Spearwood 1	Bedding plants, improved with landscaping blends
950_017	Spearwood 2	Native garden
950_018	Spearwood 3	Low maintenance lawn, topdressing sand used
950_019	Karrinyup 1	Supposed to be high maintence turf, heavily fertilised. May have been swapped with Karrinyup 5
950_020	Karrinyup 2	Vegetable garden, heavily fertilised. Improved with large applications of composts, manures, peat
950_021	Karrinyup 3	Exotic garden, as for Karrinyup 2
950_022	Karrinyup 4	Exotic garden, as for Karrinyup 2

Lab No 99A	Identification	Description
950_023	Karrinyup 5	Local park, May have been interchanged with Karrinyup 1
950_024	Waterford 1	High maintenance turf, granulated and liquid fertilisers used, not improved with soil amendments
950_025	Waterford 2	Bedding plants, improved with manures and landscaping blends, regularly fertilised
950_026	Waterford 3	As for Waterford 2
950_027	Waterford 4	Exotic garden, not improved with soil amendments, annually fertilised with granulated fertilisers
950_028	Waterford 5	Local park
950_029	Riverton 1	Low maintenance turf, has been improved with landscaping blends, granulated fertilisers used more than 1 year ago
950_030	Riverton 2	Bedding plants, as for Riverton 1, but fertilised more frequently
950_031	Riverton 3	Exotic garden, as for Riverton 1, but liquid fertilisers used in place of granulated fertilisers
950_032	Riverton 4	Bare soil
950_033	Nedlands 1	Native garden, only treated with composts
950_034	Nedlands 2	Vegetable garden, treated with composts, manures and granulated fertilisers
950_035	Nedlands 3	Low maintenance lawn, topdressing sand applied
950_036	Nedlands 4	Council park, reticulated and fertilised turf.
950_037	Nedlands 5	Bushland at Karrakatta cemetery
950_038	Morley 1	High maintenance lawn, improved with landscaping blends and topdressing sands
950_039	Morley 2	Low maintenance lawn, as for Morley 1, but without landscaping blends
950_040	Morley 3	Bedding plants, composts, manures and granulated fertilisers used
950_041	Morley 4	Exotic garden plants, as for Morley 3 but liquid fertilisers used in place of granulated products
950_042	Morley 5	Native garden, only manures and composts added
950_043	Ellenbrook 1	High maintenance lawn, unimproved soil, fertilised with granulated fertilisers
950_044	Ellenbrook 2	High maintenance lawn, improved with landscaping blends and manures

Lab No 99A	**Identification**	**Description**
950_045	Ellenbrook 3	Native garden,, has been improved as for Ellenbrook 2
950_046	Ellenbrook 4	Exotic gardens, has been improved as for Ellenbrook 2
950_047	Mt Claremont 1	Neglected turf, history prior to previous 4 years not known
950_048	Mt Claremont 2	Rose bed, composts added occasionally, history prior to previous 4 years not known
950_049	Mt Claremont 3	Garden bed, generally neglected, history prior to previous 4 years not known
950_050	Mt Claremont 4	Garden bed, generally neglected, history prior to previous 4 years not known
950_051	Mt Claremont 5	Neglected turf, history prior to previous 4 years not known
950_052	East Perth 1	Maintained turf, imported sandy soil
950_053	East Perth 2	Low maintenance garden,

APPENDIX 3

Results from Analysis of Garden Soil Samples

Lab No 99A	Identification	Sand %	Silt %	Clay %	pH $CaCl_2$	EC (1:5) mS/m	OrgC %	P (HCO_3) mg/kg	K (HCO_3) mg/kg	PRI mL/g	MED M
950_001	Daglish 1	91.0	4.0	5.0	4.7	5	2.00	120	81	7.8	0.0
950_002	Daglish 2	95.5	2.0	2.5	4.5	4	1.46	47	56	2.4	0.0
950_003	Daglish 3	95.0	2.0	3.0	5.1	18	2.46	110	140	-1.9	0.4
950_004	Daglish 4	94.5	3.5	2.0	5.1	40	8.82	150	230	-3.7	3.2
950_005	Daglish 5	96.0	2.0	2.0	5.0	3	1.52	10	<10	2.8	0.0
950_006	Duncraig 1	97.0	1.5	1.5	5.6	6	1.72	32	42	0.7	0.6
950_007	Duncraig 2	94.0	2.5	3.5	6.2	11	2.74	140	100	2.3	0.0
950_008	Duncraig 3	97.0	1.0	2.0	6.2	11	2.14	110	63	1.7	0.0
950_009	Duncraig 4	95.5	2.0	2.5	7.0	12	1.74	45	78	1.7	0.0
950_010	Duncraig 5	97.0	1.0	2.0	5.8	2	0.64	2	13	1.0	0.0
950_011	Marmion 1	97.0	1.5	1.5	6.2	9	2.77	250	79	-3.6	1.2
950_012	Marmion 2	96.0	2.5	1.5	6.5	10	3.45	180	69	4.6	1.2
950_013	Marmion 3	95.0	2.5	2.5	6.0	43	2.61	160	340	-0.4	1.4
950_014	Marmion 4	95.5	2.0	2.5	6.2	8	2.35	190	84	0.5	0.4
950_015	Marmion 5	95.5	2.5	2.0	6.2	9	1.79	97	56	3.2	0.4
950_016	Spearwood 1	96.5	1.5	2.0	6.9	12	1.51	46	77	0.0	0.0
950_017	Spearwood 2	97.0	1.5	1.5	5.8	7	1.21	57	24	-0.6	0.4
950_018	Spearwood 3	96.5	2.0	1.5	6.7	11	2.65	150	93	-2.7	1.4
950_019	Karrinyup 1	96.5	1.5	2.0	7.5	8	1.08	34	44	1.8	0.0
950_020	Karrinyup 2	95.5	2.0	2.5	7.2	9	2.20	280	47	-0.1	0.0
950_021	Karrinyup 3	94.0	3.0	3.0	7.3	24	3.20	210	100	3.1	0.4
950_022	Karrinyup 4	94.0	3.5	2.5	7.5	15	2.93	180	92	1.9	0.4

Lab No 99A	Identification	Sand %	Silt %	Clay %	pH $CaCl_2$	EC (1:5) mS/m	OrgC %	P (HCO_3) mg/kg	K (HCO_3) mg/kg	PRI mL/g	MED M
950_023	Karrinyup 5	95.5	2.0	2.5	7.8	8	1.83	130	46	2.3	0.0
950_024	Waterford 1	98.5	0.5	1.0	4.5	4	1.34	28	22	2.7	1.4
950_025	Waterford 2	98.0	1.0	1.0	5.6	8	2.11	120	30	1.4	1.6
950_026	Waterford 3	97.0	2.0	1.0	5.2	10	2.20	200	82	4.6	1.0
950_027	Waterford 4	98.0	1.0	1.0	5.7	5	0.99	54	21	1.3	0.4
950_028	Waterford 5	98.0	1.0	1.0	5.8	5	1.47	14	34	0.7	2.0
950_029	Riverton 1	98.0	1.0	1.0	6.2	5	0.61	28	21	0.1	0.0
950_030	Riverton 2	98.0	1.0	1.0	6.2	4	1.62	38	13	1.8	1.2
950_031	Riverton 3	97.0	1.5	1.5	6.2	5	1.59	49	24	2.6	0.0
950_032	Riverton 4	98.0	1.0	1.0	6.5	6	1.04	38	30	0.3	0.6
950_033	Nedlands 1	96.0	2.0	2.0	7.2	7	1.66	50	50	1.8	0.0
950_034	Nedlands 2	95.0	3.5	1.5	7.1	10	3.39	100	100	0.3	0.4
950_035	Nedlands 3	96.0	2.0	2.0	7.4	7	1.12	38	36	0.4	0.0
950_036	Nedlands 4	96.5	2.0	1.5	7.2	15	2.14	48	120	-1.1	1.2
950_037	Nedlands 5	96.0	1.5	2.5	5.6	4	1.98	3	20	1.4	0.4
950_038	Morley 1	98.0	1.0	1.0	5.6	6	2.14	9	48	1.2	1.0
950_039	Morley 2	98.5	0.5	1.0	5.5	4	1.32	10	32	0.9	1.2
950_040	Morley 3	95.5	3.0	1.5	6.0	13	5.13	120	160	-0.2	2.0
950_041	Morley 4	98.0	1.0	1.0	6.6	12	2.24	78	110	-0.3	1.4
950_042	Morley 5	98.0	1.0	1.0	6.2	5	1.44	37	59	1.3	0.4
950_043	Ellenbrook 1	98.0	1.0	1.0	7.1	8	0.62	27	21	1.1	0.0

Lab No 99A	Identification	Sand %	Silt %	Clay %	pH $CaCl_2$	EC (1:5) mS/m	OrgC %	P (HCO_3) mg/kg	K (HCO_3) mg/kg	PRI mL/g	MED M
950_044	Ellenbrook 2	98.5	0.5	1.0	6.5	4	1.04	50	18	0.0	0.4
950_045	Ellenbrook 3	99.0	<0.5	1.0	6.7	4	0.75	58	12	-0.6	0.0
950_046	Ellenbrook 4	99.0	<0.5	1.0	6.5	2	0.54	25	<10	0.0	0.0
950_047	Mt Claremont 1	98.5	1.0	0.5	6.6	3	1.35	12	18	1.3	2.0
950_048	Mt Claremont 1	95.5	2.5	2.0	7.0	8	2.00	56	52	2.7	0.0
950_049	Mt Claremont 1	97.0	1.5	1.5	6.5	12	3.15	61	110	-1.5	1.8
950_050	Mt Claremont 1	98.5	1.0	0.5	6.6	8	3.08	32	41	0.1	2.8
950_051	Mt Claremont 1	98.5	1.0	0.5	5.8	6	1.20	20	32	-0.1	2.2
950_052	East Perth 1	96.5	1.5	2.0	5.8	2	0.58	40	18	1.3	0.0
950_053	East Perth 2	97.0	1.5	1.5	6.7	6	2.37	14	36	2.2	1.0

Sand = Sand, 2.0 to 0.02 mm by NRC Method S6
Silt = Silt, 0.02 to 0.0 2 mm by NRC Method S6
Sand = Clay, less than 0.002 mm by NRC Method S6
pH (CaCl2) = pH (1:5) in 0.01 M $CaCl_2$ by NRC Method S3
EC (1:5) = Electrical Conductivity (1:5) at 25°C, by NRC Method S2
OrgC = Organic Carbon, Walkley and Black procedure, NRC Method S09
P (HCO_3) = Phosphorus, P, extracted in 0.5 M $NaHCO_3$ (1:100) by NRC Method S12
K (HCO_3) = Potassium, K, extracted in 0.5 M $NaHCO_3$ (1:100) by NRC Method S17
PRI = Phosphorus Retention Index by NRC Method S15
MED = Molarity Ethanol Droplet test
% = per cent
mS/m = milliSiemens per metre
mg/kg = milligrams per kilogram
mL/g = millilitres per gram
M = molarity

APPENDIX 4

Results from Analysis of Landscaping Soil Blends

Lab No 00A	<2mm %	Sand %	Silt %	Clay %	pH $CaCl_2$	EC (1:5) mS/m	OrgC %	Total N %	Total P mg/kg	P (HCO_3) mg/kg	K (HCO_3) mg/kg	PRI mL/g
950_001	4	93.0	2.0	5.0	6.9	7	0.47	0.033	210	35	99	1.4
950_002	33	94.5	2.5	3.0	7.2	20	2.35	0.124	940	200	110	0.6
950_003	15	92.0	3.0	5.0	7.2	24	2.02	0.104	750	200	91	2.5
950_004	50	95.5	2.0	2.5	7.0	32	4.00	0.227	1400	300	370	-1.1
950_005	13	93.5	2.0	4.5	6.8	13	0.76	0.028	220	34	29	6.1
950_006	53	96.0	1.5	2.5	6.1	190	5.73	0.208	1400	370	230	-4.0
950_007	32	93.5	3.5	3.0	6.1	27	4.34	0.194	900	150	210	10
950_008	34	96.0	2.0	2.0	6.2	160	5.99	0.193	1200	270	180	1.0

<2mm = Material removed by sieving through a 2 mm sieve
Sand = Sand, 2.0 to 0.02 mm by NRC Method S6
Silt = Silt, 0.02 to 0.0 2 mm by NRC Method S6
Sand = Clay, less than 0.002 mm by NRC Method S6
pH (CaCl2) = pH (1:5) in 0.01 M $CaCl_2$ by NRC Method S3
EC (1:5) = Electrical Conductivity (1:5) at 25°C, by NRC Method S2
OrgC = Organic Carbon, Walkley and Black procedure, NRC Method S09
Total N = Nitrogen N, total, by Method S10
Total P = Phosphorus P, total by method S14
P (HCO_3) = Phosphorus, P, extracted in 0.5 M $NaHCO_3$ (1:100) by NRC Method S12
K (HCO_3) = Potassium, K, extracted in 0.5 M $NaHCO_3$ (1:100) by NRC Method S17
PRI = Phosphorus Retention Index by NRC Method S15
% = per cent
mS/m = milliSiemens per metre
mg/kg = milligrams per kilogram
mL/g = millilitres per gram