EcoRecycle Victoria

Construction and Demolition Waste
Landfill Traffic and Compositional Surveys
Final Report

NOLAN-ITU PTY LTD

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EXECUTIVE SUMMARY

Construction and demolition waste landfill traffic and compositional surveys have been undertaken on behalf of EcoRecycle Victoria. The objective of the survey has been to guide EcoRecycle Victoria's waste reduction strategies by identifying waste quantities and the composition of materials in the construction and demolition (C&D) waste stream, and to collect data on their source.

The surveys were undertaken in April 1998 at eight landfills in metropolitan Melbourne and at two landfills in provincial cities. The eight metropolitan landfills are believed to receive at least 70 % of the total C&D waste generated in Melbourne.

A total of 371 vehicles carrying C&D wastes were surveyed. These vehicles included trucks, trailers, station wagons and cars. The total quantity surveyed was 3 332 m^3 (2 718 tonne).

The survey involved visual assessments and manual sorting of C&D loads to estimate volumes for 21 material categories. These volume estimates were then converted to weights by using material densities obtained from weighbridge measurements and other sources.

For each C&D vehicle load surveyed, information on the source of the waste was obtained by the driver. This included local government area and industry category.

The key findings from the surveys of **all landfills** are:

- The visual assessment error is typically less than 10 percent for compositional categories where the fraction by volume is greater than 10 % of the total load (eg concrete, clean soil, soil/rubble, and wood/timber).
- The average material density is 0.82 tonne/m^3.
- The density based weight estimates are generally within 20% of the weighbridge measurements.
- By volume wood/timber (25.8 %), concrete (13.6 %), clean soil (11.3 %), soil/rubble (9.8 %), garden vegetation (9.3 %), and bricks (8.7 %) are close to eighty percent of the total C&D waste stream.
- By weight concrete (20.1 %), clean soil (15.2 %), soil/rubble (13.3 %), wood/timber (7.1 %), and bricks (10.9 %) are greater than eighty percent of the total C&D waste stream.
- There is significant compositional variability between landfills. For example the proportion of timber/wood in metropolitan C&D loads varies from 10 % to 48 % of the total volume surveyed at individual landfills.
- The primary **metropolitan** industry sources are residential demolition (39 %) and commercial demolition (33 %). The other industry sources are:
  - Residential and commercial construction 15 %
  - Roads and landscaping construction and demolition 3 %
  - Civil construction and demolition 5 %
  - Other 4 %

It is suspected that some civil industry sources may have been considered by drivers to be commercial sources.

- With some 32 % of the total C&D waste, the south-east region is the largest C&D waste generator within metropolitan Melbourne. This reflects the level of residential and commercial activity within the region, and the higher percentage of the metropolitan population compared to other regions.
- The annual C&D waste quantities going to the surveyed landfills within metropolitan Melbourne is estimated to be in the order of 1.2 M tonne. (The surveyed metropolitan landfills are believed to receive at least 70 % of the total C&D waste generated in Melbourne). This estimate should be used with caution as the survey estimates do not account for weekly and seasonal variations, use density based volume conversions, and includes daily cover material (typically 15 % by volume) which is not subject to the landfill levy.
- The key difficulties experiences during the visual assessment were (i) fine material tended to agglomerate at the bottom of the load hence is likely to be underestimated, and (ii) plastic and paper tend to be overestimated due to the visual dominance of these items.

Whilst the results contained in this report are accurate for the surveys carried out, this type of survey has its limitations when applied generally and needs to be qualified. In particular, the analysis for each landfill has been based upon data collected on single days, hence does not account for weekly variability, nor seasonal factors. Therefore the results may not be fully representative of the average composition or total inputs to individual landfills.

1 INTRODUCTION

EcoRecycle Victoria (EcoRecycle), the State Government agency responsible for waste minimisation and recycling, undertakes a wide range of projects dealing with waste minimisation, recycling, residuals disposal and litter. EcoRecycle's three year business plan has identified a waste survey in the construction and demolition (C&D) sector as a priority.

The objectives of the surveys are to:

- Identify waste and recycling quantities and the composition of materials in C&D waste currently going to landfill from the following sectors:
  - Residential;
  - Commercial;
  - Roads & landscaping; and
  - Civil; and
- Collect data on the source of waste to landfill within the C&D sector to guide EcoRecycle Victoria's waste reduction strategies.

Nolan-ITU was engaged to undertake the surveys at landfill sites throughout metropolitan Melbourne, and in the provincial Cities of Ballarat, Bendigo, and Geelong.

Specific requirements of the surveys were to:

- Include major landfill sites that, when combined, receive at least 70% of the C&D waste generated;
- Record C&D waste at each site and classify it in accordance with its source from the above sectors; and
- Conduct compositional analysis of 30 randomly selected vehicles by visual assessment and manual sorting at each site.

These requirements were recommended to EcoRecycle by Maunsell (1997) in their "*Design of a Recycling and Waste Data Collection Program*" report.

2 SURVEY METHODOLOGY

2.1 Site Identification

2.1.1 Metropolitan Melbourne

Several data sources were used to identify landfills receiving at least 70 percent of the C&D waste stream in metropolitan Melbourne.

These included:

- EPA landfill levy data from 1992/93 to 1996/97;
- Regional Waste Management Group data;
- Maunsell(1993, &1994) landfill survey data; and
- GHD(1995) Waste Minimisation Strategy for metropolitan Melbourne.

The EPA landfill levy data was provided on a confidential basis.

Within the metropolitan area the quantity of C&D wastes disposed of at each licenced landfill was estimated, from EPA landfill levy data, as the 1996/97 total quantity of non-municipal waste multiplied by an applied factor. The factors were determined following consultation with landfill operators and executive officers of the relevant regional waste management groups. For inert landfills the factors ranged from 60 % to 85 %. For putrescible landfills the factors ranged from 5% to 70%.

Based upon this method the total quantity of C&D waste landfilled in the metropolitan area in 1996/97 was estimated to be 1.1 M tonne. Therefore to meet the 70% objective that the target C&D waste quantity was set at 770 000 tonne/yr.

Since 1997, some of the licenced inert landfills have closed, and others have commenced operating. This has been accounted for by redistributing the 1996/97 quantities within the region following advice from landfill operators and executive officers of the relevant regional waste management groups. Price was found to a factor which had a significant influence on the choice of landfill for C&D waste disposal. In particular, the majority of C&D waste is now disposed of to inert landfills in preference to putrescible landfills as inert landfills generally have lower operationg costs.

The final sites were selected following landfill owner confirmation that they would allow site access to the survey team.

Eight of the larger metropolitan landfills were selected for surveys, as they met the 70% criteria, provided good geographic coverage of metropolitan Melbourne, and included both inert and putrescible landfills. These are listed in Table 2.1, together with the general locality and weighbridge status. The generic names, rather than site and owner names, are provided to ensure confidentiality.

Table 2.1: Metropolitan Landfill Survey Sites

Name	Location	Landfill Type	Weighbridge	Estimated Quantity (tonne/yr)
Met A	South/East	Inert	✓	100 000
Met B	South/East	Putrescible	✓	54 600
Met C	South/East	Inert	✓	77 100
Met D	South/East	Inert	✗	34 400
Met E	North/West	Putrescible	✓	86 200
Met F	North/West	Inert	✓	213 100
Met G	North/West	Inert	✗	63 200
Met H	North/West	Inert	✓	140 400
Total				**769 000**

Weighbridges were not operating at the Met A and Met B sites on the days that these landfills were surveyed.

2.1.2 Provincial Victoria

The selected provincial city licenced landfills are listed in Table 2.2.

Table 2.2: Provincial City Landfill Survey Sites

Name	Location	Landfill Type	Weighbridge	Estimated Quantity (tonne/yr)
Prov A	-	Inert	✓	15 000
Prov B	-	Putrescible	✓	25 000
Prov C	-	Inert	✓	7 300
Total				**47 300**

2.2 Classification System

The adopted twenty one compositional categories used for all surveys are:

Paper/Cardboard	Plastics	Concrete
Garden/Vegetation	Metals	Plasterboard
Wood/Timber	Hazardous Wastes	Bricks
Carpets	Ceramics	Asphalt/Bitumen
Other Textiles	Soil/Rubble <150mm	Cement Sheet.
Rubber	Cobbles/Boulders	Insulation
Glass	Clean Soil	Others

The categories are in general, in accordance with the classification system proposed by the brief. The exceptions are:

- Carpet was included as an additional category (The brief lumped carpet with textiles);
- Hazardous waste was included as an additional category. Fluorescent globes, asbestos, and paint (as listed in the brief) were lumped together as hazardous wastes; and
- Garden/vegetation, rubber, and "other" were included as additional categories.

Subcategories of concrete, wood, metals, ceramics, and plastics were not included in the survey due to the difficulty in separating these into the minor components (particularly for plastics). These difficulties included obscuring of small fractions by the more dominant heavier fractions, and problems in distinguishing between subcategories (such as concrete and reinforced concrete, and particle board and other wood).

2.3 Material Densities

Whilst the survey data is recorded as volume, the results are presented as both volume and weight.

The densities used to convert from volume to weight were derived from weighbridge data for mono-loads, reference documents, and experience with other C&D landfill surveys. The references included Tchobanoglous et al (1993), Wilbertz(1985), and Steiner(1998). (A brief review of Australian literature did not reveal any records of landfill C&D density measurements).

Densities for material mono-loads were obtained from weighbridge measurements for wood/timber, metals, cobbles/boulders, clean soil, concrete, and asphalt/bitumen. The results are presented in Table 2.3.

Table 2.3: Mono-load Densities (Tonne/m^3)

Material	Density
Wood/Timber	0.3
Metals	0.9
Soil/Rubble <150mm	2.4
Cobbles/Boulders	1.4
Clean Soil	1.6
Concrete	1.5
Asphalt/Bitumen	0.8

The densities adopted for each of the 21 compositional categories are listed below.

Table 2.4: Material Densities (Tonne/m^3)

Material	Density	Material	Density	Material	Density
Paper/Cardboard	0.1	Plastics	0.2	Concrete	1.5
Garden/Vegetation	0.15	Metals	0.9	Plasterboard	0.2
Wood/Timber	0.3	Hazardous Wastes	0.2	Bricks	1.2
Carpets	0.3	Ceramics	1.0	Asphalt/Bitumen	0.8
Other Textiles	0.15	Soil/Rubble <150mm	1.4	Cement Sheet.	0.5
Rubber	0.3	Cobbles/Boulders	1.4	Insulation	0.05
Glass	0.7	Clean Soil	1.6	Others	0.3

The aggregated weights of all surveyed vehicles, based upon the above densities, have been compared with weighbridge measurements obtained for six landfills. The density based estimates are generally within 20% of the weighbridge figures (Section 3.2).

2.4 Site Inspections and Meetings

Prior to conducting the surveys on-site meetings were held with all landfill owners and operators. The objectives of the meetings were to:

- Advise the operators about the study objectives;
- Seek input on the OHS arrangements on site;

- Determine the survey day/date; and to
- Discuss and confirm the operational arrangements.

Operational issues included the availability of weighbridge/gatehouse data, the transfer of vehicle identification and net load weight data to recording forms, suitable areas to conduct sample sorting, and site specific strategies to ensure reliable data collection.

2.5 Survey Methodology

The surveys at each landfill involved:

- Monitoring at the landfill gate;
- Visual assessment of loads; and
- Physical sorting of loads.

Visual assessment was the primary tool to determine the waste composition. Physical sorting was used as a visual assessment calibration tool.

2.5.1 Landfill Gate Monitoring

A staff member was placed at the gate to:

- Determine whether vehicles carried predominantly C&D wastes;
- Select vehicles for visual assessment;
- Determine the source industry and source area of the C&D load; and
- Direct selected vehicles to the assessment area.

Load Determination

Drivers were asked to advise on whether the material was predominantly C&D waste material. Vehicle selection was then made following a visual inspection of the load.

Vehicle Selection

The survey requirement was that 30 vehicles be surveyed at each landfill. Vehicles were categorised as open truck, enclosed truck, single axle trailer, car/station wagon, and other.

During the survey trial, it was found that up to 60 vehicles could be visually assessed in any given day. For this reason, it was decided that all vehicles would be surveyed unless at the time of entry there were four vehicles in the assessment area.

Source Industry and Area Determination

Drivers were asked to identify the industry categories, and the local government area, from which the vehicle was travelling. The industry categories were:

- Residential construction;
- Residential demolition;
- Commercial construction;
- Commercial demolition;
- Roads and landscaping construction;
- Roads and landscaping demolition;
- Civil construction;
- Civil demolition; and
- Other.

Private traffic sourced residential construction and demolition waste has been included in the survey.

The Assessment Area

The assessment area was generally at or adjacent to the landfill operating face.

2.5.2 Visual Assessment

Visual assessment was used to estimate the total load volume, and the volume of individual fractions for each of the compositional categories. It involved the following steps:

1) Observing the unloading. This allowed for the identification of hidden fractions, and indicates the load homogeneity;
2) Estimate of the total load volume (i.e. vehicle waste volume);
3) Marking of identified categories on the data sheets;
4) Estimation of all category volumes, commencing with the major categories; and
5) Checking of that the volume estimation of the individual categories added up to about 100%.

Each load was evaluated by two assessors. The adopted proportions were the mean of the two estimates.

2.5.3 Physical Sorting

Physical sorting was conducted at the first metropolitan landfill site to calibrate visual assessment estimates.

It involved:

- Separating the load, or load components, into segregated fractions with a front end loader and/or manually; and
- Visual assessment of the category volumes.

In all cases the physical sorting assessment was conducted independent of the visual assessment. The results were then compared with the assessor's visual assessment.

The difference between the results of the visual and physical sorting estimates were generally less than 10 percent for the major compounds where the proportions were greater than 10% by volume (eg concrete, clean soil, soil/rubble, and wood/timber) and up to 100% for minor categories such as cobbles/boulders, ceramics, asphalt/bitumen, plasterboard, plastics where the proportions were less than 2 % by volume.

Regular re-calibration of the visual assessors was performed by the site supervisor.

2.6 Training of Assessors

Each survey was undertaken by a team of six assessors, and a team leader. For each landfill, the assessors were selected from a group of twelve RMIT University (Environmental Engineering) students all of whom met the inoculation standards, and underwent a training course.

The training course included a workshop session and on-site instruction at one of the metropolitan landfills. Training involved instruction in:

- Survey objectives;
- Occupational health and safety plan (Appendix A).
- Survey procedures;
- Procedures for completing the visual assessment (Form A), physical sorting (Form B), and base data collection at the gate (Form C). These forms are reproduced in Appendix B.

3 SURVEY DATA AND RESULTS

The survey data has been tabulated to show:

- Overall survey statistics;
- Waste composition, as percentage volume and weight, for individual landfills;
- Aggregated waste composition, as percentage volume and weight, for metropolitan and provincial city landfills;
- Aggregated metropolitan waste volume and weight, by source industry;
- Aggregated metropolitan waste composition and tonnages, by LGA; and
- Estimated total annual volumes.

Tabulated summary sheets for all landfills are attached as Appendix C.

3.1 Survey Schedule

All surveys were undertaken between April 6 1998 and April 24 1998. The dates and survey hours are listed in Table 3.1. The survey hours generally correspond to operational hours.

Table 3.1: Survey Schedule

Landfill Site	Date	Day	Survey Hours
Met A	24.4.1998	Friday	7am-4pm
Met B	20.4.1998	Monday	7.30am-4pm
Met C	9.4.1998	Thursday	7.30am-3.30pm
Met D	18.4.1998	Saturday	8am-1pm
Met E	15.4.1998	Wednesday	8am-4pm
Met F	17.4.1998	Friday	8am-4pm
Met G	7.4.1998	Tuesday	7.30am-3.30pm
Met H	16.4.1998	Thursday	8am-4pm
Prov A	8.4.1998	Wednesday	8am-16pm
Prov B	6.4.1998	Monday	7.30am-4.30pm
Prov C(1)	14.4.1998	Tuesday	7.30am-12pm
(1) Survey cancelled due to absense of C&D vehicles			

Landfill Prov C is not included in any of the data analysis, as the survey was abandoned due to an absence of vehicles with C&D loads entering the site. (An attempt was made to conduct the survey at another landfill that also served the provincial city. Unfortunately access to the site was denied by the owner).

3.2 Vehicle Load Statistics

Table 3.2 presents the number of vehicles, average vehicle loads, surveyed volumes and weight for each landfill and in total.

Table 3.2: Waste Quantities

Landfill Site	No. of Vehicles		Volume [m^3]		Average Density [t/m^3]	Weight [tonne]
	Total during survey period	Surveyed	Average Vehicle	Total		
Met A	27	25	14.9	373	1.13	393
Met B	47	36	18.6	670	0.76	507
Met C	130	61	5.3	325	0.86	280
Met D	87	59	5.4	318	0.93	295
Met E	29	28	3.3	94	0.94	82
Met F	85	37	8.0	295	0.65	192
Met G	64	44	13.2	581	0.91	531
Met H	55	45	11.8	532	0.61	326
Prov A	23	20	4.8	95	0.74	81
Prov B	18	16	3.1	49	0.82	41
Total	**565**	**371**	**-**	**3332**	**-**	**2728**

The average number of vehicles surveyed per site was 37.

The estimated waste mass surveyed has been calculated by applying the adopted density figures to the various waste categories. These estimates are compared with weighbridge measurements from six of the surveyed landfills in Table 3.3.

Table 3.3: Weighbridge and Density Estimated Loads (Tonne)

Landfill Site	Density Estimate	Weighbridge Measurement	Error
Met C	280	293	-4.5%
Met E	82	88	- 6.8%
Met F	192	159	+20.7%
Met H	326	293	+11.2%
Prov A	70	81	-15.6%
Prov B	49	41	+19.5%

The error margin between the density estimates and the weighbridge measurements are typically less than 20%.

3.3 Waste Composition Analysis

The composition of the waste has been estimated on both a volume and weight basis for individual landfills, and aggregated Metropolitan and Provincial City landfills. In the sub-sections that follow, we provide a description of our approach to estimating waste composition and an overview of the key findings from this analysis. The full results, including graphical presentations, and error margins, are presented in Appendix D.

Plots of the aggregated waste composition (by both volume and weight) are shown for the metropolitan landfills in Figure 3.1 and for provincial landfills in Figure 3.2.

3.3.1 Analysis Approach

Individual site volume and weight composition:

- For each truck surveyed the volume of each waste type was recorded.

  ie for truck 1 to truck n, volume of wood/timber, concrete etc was recorded.

- Volumes of individual waste types were aggregated to establish the total volume of waste of each type at each site.

  ie volume of each waste recorded for trucks 1 to n was aggregated to produce a total volume of each waste deposited by trucks 1 to n..

- Weight of waste at each site was derived from the total volume of each waste type and the densities (described earlier).
- The total volume and weight of waste at each site was calculated by adding together the individual volumes/individual weights of each type.

ie total volume of waste = total volume (wood/timber) + total volume (concrete) etc.

ie total weight of waste = total weight (wood/timber) + total weight (concrete) etc.

- Volume/weight of each waste type could then be expressed as a percentage of total volume at each site.

$$eg \quad Percentage\ (wood/timber) = \frac{Volume\,(wood/timber)}{Total\ volume of\ waste\ from trucks 1 to n}$$

$$Percentage\ (wood/timber) = \frac{Weight\ (wood/timber)}{Total\ weight\ of\ waste\ from trucks 1 to n}.$$

Overall volume/weight percentages:

- For each truck surveyed the volume/weight of each waste type was recorded.
- The volume and weight of every waste type for every truck surveyed across all depots was aggregated to produce an overall total volume/weight for each type of waste.
- The total volume and weight of waste at all sites was calculated by adding together the individual overall volumes/overall weights of each type.
- Volume/weight of each waste type could then be expressed as a percentage of total volume at all sites.

Error margins for volume and weight proportions:

- Error margins were calculated to provide an indicative measure of the statistical accuracy for the individual proportions of wastes reported, for the survey day and over a year.

  For example a reported margin of error of ± 6% at Met D for the survey day, tells us that we can be 95% confident that:

  - *the actual proportion of wood/timber deposited on the survey day (by volume) was 19% ± 6% (at worst) (ie we can be 95% confident that the actual value was in the range of 13% to 25%);*
  - *likewise it tells us that the actual proportion concrete deposited on the survey day (by volume) was 13% ± 6% (at worst) (ie we can be 95% confident that the actual value was in the range of 7% to 20%); and*
  - *so on for all other wastes measured.*

- Because a much larger number of trucks is expected to enter each site over a year, compared to a single day, it makes sense that we have less confidence about extrapolating a day's data to a year. Accordingly the error margins for extrapolating to a year are greater.
- The statistical formulae used to calculate the error margins for the survey day and over a year are appended.

- Given that the error margin will vary with the estimated percentage of each reported waste category, in the detailed results sheets for each site, we have only reported the maximum expected error margin. However, the formulae in Appendix E, can be applied to calculate the specific error margins for any particular waste category, at any particular site, as required.

The compositional data presented in Survey Summary Sheets (Appendix C) presents 95 % confidence intervals with and without finite population corrections. Finite population corrections are typically applied when the sample size is a greater than 10% of the total. This correction factor has been applied to the *error margin for the survey day* as presented in the results of the compositional analysis sheets (Appendix D).

3.3.2 Key Findings

Plots of the aggregated waste composition (by both volume and weight) are shown for the metropolitan landfills in Figure 3.1, for provincial landfills in Figure 3.2, and for all landfills in Figure 3.3.

The key findings from the surveys of all landfills are:

- The visual assessment error is typically less than 10 percent for compositional categories where the fraction by volume is greater than 10 % of the total load (eg concrete, clean soil, soil/rubble, and wood/timber).
- The average material density is 0.82 tonne/m^3.
- The density based weight estimates are generally within 20% of the weighbridge measurements.
- By volume wood/timber (25.8 %), concrete (13.6 %), clean soil (11.3 %), soil/rubble (9.8 %), garden vegetation (9.3 %), and bricks (8.7 %) are close to eighty percent of the total C&D waste stream.
- By weight concrete (20.1 %), clean soil (15.2 %), soil/rubble (13.3 %), wood/timber (7.1 %), and bricks (10.9 %) are greater than eighty percent of the total C&D waste stream.

The key findings for metropolitan landfills are:

- By volume wood/timber (25.9 %), concrete (13.9 %), clean soil (11.8 %), soil/rubble (9.3 %), garden vegetation (9.6 %), and bricks (8.5 %) are close to eighty percent of the total C&D waste stream.
- By weight concrete (25.4 %), clean soil(23.0 %), soil/rubble (15.9 %), wood/timber (9.5 %), and bricks (12.5 %) are greater than eighty percent of the total C&D waste stream.
- There is a large degree of compositional variation between landfills. For example the proportion of timber/wood in metropolitan C&D loads varies from 10 % to 48 % of the total volume surveyed at individual landfills.

The weight based compositional analysis for metropolitan Melbourne is compared with the Maunsell (1993) data in Table 3.4. The Maunsell analysis is based on 15 vehicles only.

Table 3.4: Comparison of Survey Results with Maunsell (1993)

Category	Maunsell (1993) [% by weight]	Survey [% by weight]
Paper/Cardboard	1.2	0.4
Garden/Vegetation	0.1	1.7
Wood/Timber	12.2	9.5
Carpets and Other Textiles	1.2	0.5
Rubber	1.1	0.1
Glass	0.5	0.2
Plastics	1.1	0.5
Metals	7.3	4.5
Ceramics	4.5	0.9
Soil/Rubble, Cobbles/Boulders,& Clean Soil	41.7	40.9
Other (1)	29.0	40.8
Total	100	100

(1) Other includes concrete, plasterboard, bricks, asphalt/bitumen, cement sheet, and insulation

The significantly higher quantity of garden/vegetation material in the 1997 survey (1.7 %) compared with the 1993 survey (0.1 %) probably reflects the smaller 1993 sample size, and that the 1993 compositional survey was limited to building and demolition wastes and hence may have excluded roads and landscaping demolition and construction materials.

Figure 3.1: Composition of C&D Waste at Metropolitan Landfills

Figure 3.2: Composition of C&D Waste at Provincial Landfills

Figure 3.3: Composition of C&D Waste at All Landfills

There is also a significant difference in the “Other” category. The reason for this is not clear as it is not known whether concrete and bricks are included as “Other” or as clean fill (ie Soil/Rubble, Cobbles/Boulders, &Clean Soil) in the 1993 survey.

There is a significant difference between the C&D waste composition of both Provincial landfills compared to the aggregated Metropolitan landfills. This may be due to the small Provincial landfill sample size.

3.4 Industry Sources

The industry source information has been aggregated for metropolitan Melbourne. The results are presented, as volumes and percentage volumes, for each industry source category in Table 3.5.

This table shows that, based upon the survey data, the primary industry sources, with a combined percentage of 73 %, are residential and commercial demolition. It is suspected that some civil sources may have been considered to be commercial sources.

Table 3.5: Distribution of Industry Sources

Industry Source	Volume	
	[m^3]	[%]
Residential construction	278	10.5
Residential demolition	1043	39.3
Commercial construction	131	4.9
Commercial demolition	884	33.3
Roads and landscaping construction	46	1.7
Roads and landscaping demolition	31	1.2
Civil construction	105	4.0
Civil demolition	22	0.8
Other (1)	114	4.3
Total	2654	100

(1) Other covers loads in which the driver was not able to identify the category

Table 3.6: Distribution of Geographic Sources

Region	Local Government Area	Volume [m³]	Volume [%]
West	Wyndham	42	1.3
	Melton	8	0.3
	Yarra	97	3.1
	Port Phillip	121	3.8
	Brimbank	57	1.8
	Hobsons Bay	67	2.1
	Maribyrnong	12	0.4
	Moonee Valley	122	3.8
	Melbourne	136	4.3
	Total		**20.9**
North	Hume	153	4.8
	Moreland	26	0.8
	Whittlesea	190	6.0
	Darebin	127	4.0
	Banyule	109	3.4
	Nillumbik	129	4.0
	Total		**64.8.0**
South-east	Bayside	26	0.8
	Glen Eira	94	2.9
	Stonnington	0	0.0
	Boroondara	64	2.0
	Monash	94	2.9
	Kingston	362	11.4
	Greater Dandenong	267	8.4
	Frankston	33	1.0
	Casey	68	2.1
	Cardinia	0	0.0
	Total		**161.1**
East	Manningham	78	2.4
	Whitehorse	300	9.4
	Knox	36	1.1
	Maroondah	90	2.8
	Yarra Ranges	0	0.0
	Total		**337.9**
Mornington Peninsula	Mornington Peninsula	0	0.0
Unkown/Other		279	8.8
Total			**684.6**

3.5 Source Areas

C&D waste have also been aggregated into local government source areas to obtain an overall estimate of the regional distribution. The results are presented in Table 3.6.

The tabulated results provide a general perspective of the regional distribution. The reliability of the results are limited by the fact that not all landfills were surveyed, and that some LGA's may be under-represented. Futhermore the distribution is only a snap shot in time. It does however indicate that the south-east region is the largest generator. This reflects the high level of residential and commercial activity within the region, and the higher percentage of the metropolitan population compared to other regions.

3.6 Annual Quantities

Annual C&D waste quantities going to all surveyed landfills have been estimated (Table 3.7). It has been assumed that the survey period is representative of the full year. These survey estimates are then compared with the 1996/97 landfill levy estimates after application of the C&D correction factor (Section 2).

Table 3.7: Estimated Annual Landfill C&D Quantities (Tonne/Year)

Landfill	Vehicles		Quantity [tonne]		Days/week	Annual Quantities [tonne]	
	Surveyed	Total/Weekday	Surveyed	Per Day		Survey	1996/97
Met A	25	27	393	425	5.5	121 700	100 000
Met B	36	47	507	662	7	241 700	54 600
Met C	61	130	280	598	6.9	215 100	77 100
Met D	59	95	295	875	5.5	136 200	34 400
Met E	28	29	82	85	7.0	30 900	86 200
Met F	37	85	159	408	6.8	144 500	213 100
Met G	44	64	531	773	5.9	237 700	63 200
Met H	45	55	293	365	5.3	100 800	140 400
Total Met						**1 228 600**	**769 000**
Prov A	20	23	81	91	7	33 200	15 000
Prov B	16	18	41	46	5.9	14 000	25 000
Total Prov						**47 200**	**40 000**

These estimates should be used with caution as the survey estimates:

- Are only representative of the city in which the survey was conducted and hence do not account for weekly and seasonal variations;

- For landfills, without weighbridges or where the weighbridges were not operational, the quantities have been derived from density estimates. These have been shown to be up to 20% in error.
- The surveyed landfills may be accepting a greater proportion of the C&D waste than occurred in 1996/97; and
- These estimates include clean fill which is exempt from the landfill levy.

4 DISCUSSION

Representativeness of Landfill Sites

The eight metropolitan landfills surveyed are considered to accept at least 70% of the total quantity of C&D waste disposed of to landfill within metropolitan Melbourne. This assessment, originally based upon the 1996/97 EPA landfill levy data, is supported by the fact that the estimated annual C&D quantities are greater than the EPA levy estimate.

It was only possible to obtain survey data at two of the three provincial city landfills, as at one of the cities the main municipal landfill did not receive any C&D waste over the survey period, and the other major C&D landfill operator in the area did not consent to the survey occurring.

In extrapolating beyond individual sites, to provide an overall picture, it is assumed that the sites surveyed are representative or typical of all sites in general.

Landfill Owner Support

With the exception of two landfill owners, site access was provided by all those contacted. The landfill operators also provided on-site assistance and support.

Use of Weighbridges

Whilst nine of the eleven landfills had weighbridges, only six of these were used to weigh all vehicles entering the sites during the survey period.

Survey Methodology

The survey team of six spent one day, generally from opening to closing time, at each landfill. This enabled recording of the total number of vehicles for the day, allowing us to accurately compute the margins of error for waste proportions. The number of vehicles surveyed at each metropolitan site was greater than 25. At the two Provincial City landfills, 16 and 20 vehicles were surveyed. The lower number was due to less frequent usage of that landfill.

Across all sites, an average of 37 vehicles were surveyed per site.

Information on source industry and local government area was obtained from each driver as they entered the site.

The loads of all vehicles carrying C&D loads were visually assessed into 21 categories. Manual sorting at the first landfill surveyed was used to calibrate the assessors' volume based estimates. During each the the surveys the supervisor regular checked the results of the assessors.

Difficulties experienced with the visual assessment were:

1) Fine material tended to agglomerate at the bottom of the load hence they may have been underestimated.

2) Plastic and paper may have been to be overestimated due to the visual dominance of these items in the load.

The error identified during calibration was typically less than 10% for major categories, and up to 100% for minor categories (defined as categories comprising less than 3% of the load).

Conversion of Volume to Weight

Volumes were converted to weight by applying material densities. These densities were derived from weighbridge data for mono-loads, reference documents, and experience with other C&D landfill surveys. Weight estimates, obtained from volume conversions, were checked with weighbridge measurements at six landfills. The estimates were generally within 20 % of the weighbridge measurements.

Limitations of Extrapolation of the Compositional Analysis

The error margin for the day corresponds to the maximum margin or error for the survey day around any proportion shown in the graph, assuming that the trucks sampled are *representative of all* trucks that visited the site on the survey day. For example, we can be 95% confident that at Met B, 28% ± a minimum of 15% of waste by volume was wood/timber.

Extrapolation of results at each site to a year, based on a single day's data carries an additional important assumption:

➢ That the survey day at each site was a representative or typical day, with respect to weather conditions, other seasonal variations and weekly variations that may be related to the composition of materials deposited at each site.

Extrapolation of results to overall results, based on a individual site data will, to some extent, remove any potential biases associated with weather conditions, other seasonal variations and weekly variations. This is a reasonable inference, as the data from all sites combined was collected over a number of days, when a range of weather conditions would have prevailed. However when extrapolating to an overall results it is assumed that:

➢ The sites sampled, are representative of all sites; and

➢ Collectively data was collected to cover different daily patterns, weather conditions and so on.

Reliability of the Source Industry and Area Data

The industry source data appears to underestimate civil construction and demolition waste, and overestimate commercial waste. This may in part be due to drivers' uncertainty about the industry source classifications.

The LGA source data appears to reflect the population in general, and higher levels of construction and demolition activity in the south-east.

Limitations

Whilst the results contained in this report are accurate for the surveys carried out, this type of survey has its limitations when applied generally and needs to be qualified. In particular, the analysis for each landfill has been based upon data collected on single days, hence does not account for weekly variability, nor seasonal factors. Therefore the results may not be fully representative of the average composition or total inputs to individual landfills.

5 REFERENCES

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Appendix A

Occupational Health and Safety Plan Instructions

Appendix B

Landfill Survey Procedures

Appendix C

Survey Summary Sheets

Appendix D

Results of Compositional Analysis

Appendix E

Formulae for Calculating Error Margins

Appendix E
Formulae for Calculating Error Margins

A 95% confidence interval for a proportion is given by:

$$p - 1.96 * \sqrt{\frac{p(1-p)}{n}} * \sqrt{(1-f)} \leq P \leq p + 1.96 * \sqrt{\frac{p(1-p)}{n}} * \sqrt{(1-f)}$$

where p is the proportion of a particular type of waste (by volume or weight) as reported from the survey,

and p is an unbiased estimator of P, being the population proportion (ie the best estimate we have of the actual proportion, assuming our sampling approach is unbiased).

n is the sample size (being the number of trucks sampled at the site or overall).

f is the sampling fraction and is equal to $\frac{n}{N}$, where N is the total number of trucks that visited the site during the survey day or for a year. If f is very small or N is unknown (as is the case when calculating the error margin for a year) then $\sqrt{(1-f)}$ may be omitted from the equation.

For a given sample size, and level of confidence, as an estimated percentage approaches 50%, so the errror margin increases. Conversely, as the estimated proportion approaches, 0% or 100%, the error margin decreases. The worked examples below illustrate this point.

Example 1

Let's say we estimate that the proportion of concrete deposited at a site on the survey day was 10%, based on data collected from 50 out of 70 trucks that visited the depot on the survey day, the error margin for the survey day, at a 95% confidence level, would be calculated as follows:

$p = 10\%,\ n = 50, N = 70$

Hence,

$$\Rightarrow \quad 0.10 - 1.96 * \sqrt{\frac{.10(1-0.10)}{50}} * \sqrt{\left(1-\frac{50}{70}\right)} \le \quad P \quad \le 0.10 + 1.96 * \sqrt{\frac{.10(1-0.10)}{50}} * \sqrt{\left(1-\frac{50}{70}\right)}$$

$$\Rightarrow \quad 0.10 - 1.96 * \sqrt{.0018} * \sqrt{.2857} \le \quad P \quad \le 0.10 + 1.96 * \sqrt{.0018} * \sqrt{.2857}$$

$$\Rightarrow \quad 0.10 - 1.96 * .042 * .535 \le \quad P \quad \le 0.10 + 1.96 * .042 * .535$$

$$\Rightarrow \quad 0.10 - 0.04 \le \quad P \quad \le 0.10 + 0.04$$

$$\Rightarrow \quad 0.06 \le \quad P \quad \le 0.14$$

Hence for this hypothetical site, we can be 95% confident that the true proportion of concrete deposited was 10% ± 4%, on the survey day.

If we were interested in knowing the error margin for an extrapolation to a year, we would simply delete the *(1-f)* term from the calculation, on the basis that the sample taken on the day, is relatively small compared to the total number of truck visits to the site in a year.

Returning to our example, the error margin for the year is calculated as follows:

$$\Rightarrow \quad 0.10 - 1.96 * .057 \le \quad P \quad \le 0.10 + 1.96 * .057$$

$$\Rightarrow \quad 0.10 - 0.08 \le \quad P \quad \le 0.10 + 0.08$$

$$\Rightarrow \quad 0.02 \le \quad P \quad \le 0.18$$

Hence for this hypothetical site, we can be 95% confident that the true proportion of concrete deposited over a year would be 10% ± 8%[1].

[1] To extrapolate, we are assuming that the survey day can be treated as an 'average' or typical day at that site.

Example 2

Let's say we estimate that the proportion of concrete deposited at a site on the survey day was 50%, based on data collected from 50 out of 70 trucks that visited the depot on the survey day, the error margin for the survey day, at a 95% confidence level, would be calculated as follows:

$$p = 50\%, \ \ n = 50, N = 70$$

Hence,

$$\Rightarrow \quad 0.50 - 1.96 * \sqrt{\frac{.50(1-0.50)}{50}} * \sqrt{\left(1-\frac{50}{70}\right)} \leq \quad P \quad \leq 0.50 + 1.96 * \sqrt{\frac{.50(1-0.50)}{50}} * \sqrt{\left(1-\frac{50}{70}\right)}$$

$$\Rightarrow \quad 0.50 - 1.96 * \sqrt{.005} * \sqrt{.2857} \leq \quad P \quad \leq 0.20 + 1.96 * \sqrt{.005} * \sqrt{.2857}$$

$$\Rightarrow \quad 0.50 - 1.96 * .071 * .535 \leq \quad P \quad \leq 0.50 + 1.96 * .071 * .535$$

$$\Rightarrow \quad 0.50 - 0.07 \leq \quad P \quad \leq 0.50 + 0.07$$

$$\Rightarrow \quad 0.43 \leq \quad P \quad \leq 0.57$$

Hence for this hypothetical site, we can be 95% confident that the true proportion of concrete deposited was 50% ± 7%, on the survey day.

If we were interested in knowing the error margin for an extrapolation to a year, we would simply delete the *(1-f)* term from the calculation, on the basis that the sample taken on the day, is relatively small compared to the total number of truck visits to the site in a year.

Returning to our example, the error margin for the year is calculated as follows:

$$\Rightarrow \quad 0.50 - 1.96 * .071 \leq \quad P \quad \leq 0.50 + 1.96 * .071$$

$$\Rightarrow \quad 0.50 - 0.14 \leq \quad P \quad \leq 0.50 + 0.14$$

$$\Rightarrow \quad 0.36 \leq \quad P \quad \leq 0.64$$

Hence for this hypothetical site, we can be 95% confident that the true proportion of concrete deposited over a year would be 50% ± 14%[2].

[2] To extrapolate, we are assuming that the survey day can be treated as an 'average' or typical day at that site.