Appendix A : Field Audit Methodology

The methodology for the project was developed specifically for this audit, with the aims of ensuring that:

- accurate, reliable and statistically valid data was collected
- measurements were weight-based avoiding the inherent errors of visual estimation
- appropriate sampling techniques provided useful data within the available budget.

The methodology therefore combined a desktop audit with a weight-based physical field audit. The field component was based upon a series of sampling techniques to enable the mixed C&D waste stream of interest to be accurately and efficiently targeted.

The audit was undertaken in the Sydney Metropolitan Area (SMA) because:

- 72% of C&D waste disposed of in NSW is disposed of in the SMA[3]
- the nature of the landfilling industry in the SMA is different to that of the rest of NSW. In particular, the SMA has more recycling and reprocessing facilities, whereas landfilling of C&D waste in the rest of NSW tends to occur as co-disposal with other types of waste
- budget constraints.

A-1 Preliminary Desktop Audit

Disposal data of C&D waste to landfills in the SMA is collected through the Waste Contribution Monthly Reports (WCMR) submitted by landfills in association with payment of the waste levy required by Section 88 of the *Protection of the Environment Operations Act, 1997*.

The first stages in developing the field audit was to undertake a desktop analysis of the WCMRs. This analysis identified quantities of material disposed of as segregated loads such as contaminated soil and asbestos and the quantity of mixed C&D waste disposed (unsegregated loads). Knowing the quantities of segregated loads disposed to landfill meant that there was no requirement to include these materials in the physical audit. This allowed the focus to be on identifying the composition of the mixed C&D waste.

A-2 Field Composition Audit

The methodology used for the composition audit was developed to target the mixed waste component of the C&D waste stream as well as avoid the inherent inaccuracies associated with using visual-based assessment. These inaccuracies appear to be particularly significant when using visual assessment methods to quantify fine materials in a mixed waste sample which are significant components of mixed C&D waste. Fine materials in a stockpile cannot be observed by visual-based assessment techniques so timber and large waste materials are over-estimated.

A new auditing methodology based on measurement by weight was therefore developed. The methodology employed sampling techniques based on particle size and source flow of mixed C&D waste materials. A summary of the methodology is provided below.

3 *Waste Avoidance and Resource Recovery in NSW – A Progress Report, 2004*

A-2-1 Landfill Site Selection

The desktop audit of the WCMRs identified the top ten landfills disposing of C&D waste in the SMA.

The top ten landfills were then surveyed by personal interview with the landfill manager to identify the:

- life stage of the landfill (landfills undertaking closure works were excluded)
- suitability of each landfill for conducting the audit on site
- main source flows of mixed C&D waste to the landfill
- daily vehicle movements for stockpile construction.

The results identified five landfills that met the requirements for undertaking the field audit. All agreed to participate in the project once issues of safety and confidentiality had been addressed.

The five landfills selected for the mixed C&D waste audit accounted for:

- 88% of the mixed C&D waste disposed to landfill in the SMA
- 77% of all C&D waste disposed to landfill in the SMA.[4]

A-2-2 Sampling Regime

A-2-2-1 Source Flow Sub-Streams

The interviews with each landfill manager identified vehicle type as the predominant characteristic used to determine the flow source of mixed C&D waste on site. Using this method of classification, eleven distinct sub-streams of C&D waste were identified. A stratified sampling plan was then developed based on the quantity of mixed C&D waste disposed within each waste flow sub-stream. This information was used to determine how many stockpiles were required for each identified sub-stream to ensure the collection of representative data.

A-2-2-2 Gatehouse Activities

Random sampling was used to determine which of the vehicles delivering mixed C&D waste within each sub-stream to the landfill were diverted for stockpile construction. Stockpiles were used to ensure that the waste was well mixed and representative of each waste sub-stream.

A-2-2-3 Stockpile Construction

Stockpiles of C&D waste were constructed for each waste flow sub-stream. As a vehicle was identified as belonging to a waste flow sub stream of interest it was directed to unload in a particular stockpile. Loads continued to be directed to stockpiles until the stockpile was 100m^3.

Mechanical plant (front-end loaders, excavators, bobcats etc) were used to thoroughly mix the loads contributing to each stockpile, after each new load, and again once the stockpile had been completed. Photograph 1 shows one of the stockpiles being mixed by mechanical plant prior to sampling for analysis.

Photograph 1 – Mechanical mixing of large stockpile

4 Data based on analysis of Waste Contribution Monthly Reports.

A-2-2-4 Stockpile Sampling

A sample of 8-15m^3 was removed from the 100m^3 stockpile for analysis. A cross-section of material, down to the base of the stockpile, was taken from each stockpile after it had been built and thoroughly mixed.

A-2-2-5 Waste Sorting and Analysis

All stockpile samples (8-15m^3) were sorted into size fractions through a combination of manual and mechanical sorting processes. The different particle-size fractions used in this analysis were as follows:

- greater than 300mm (large)
- 30mm to 300mm (medium)
- 4.75mm to 30mm (small)
- less than 4.75mm (fines).

The waste material classifications used in the sorting are detailed in Appendix B.

Manual sorting was initially used to separate the large-size fraction (>300mm) from the sample and each individual piece of material was recorded and measured. The material type, dimensions (height x length x width) and weight of each item were recorded.

The remaining sample was then loaded into the mechanical sorting plants (Photographs 2 and 3).

Photograph 2 – Doppelstadt trommel with picking belt, for manual sorting

Photograph 3 – Pitbull screening plant with picking belt, for manual sorting

The medium-size fraction (30-300mm) of the sample was discharged from the mechanical sorting plant along a manual picking belt. A team of waste auditors manually sorted the medium fraction material into the waste classifications detailed in Appendix B. Each of the sorted waste material categories was weighed and recorded. This is shown in Photograph 4.

All material less than 30mm was screened into a skip bin (see Photograph 5) and weighed. Two 20L containers of material (minimum 40kg) were collected from the sample and sent to a geotechnical laboratory to undergo further analysis.

Material in the small-size fraction (4.75-30mm) underwent particle-size and compositional analysis. All material less than 4.75mm was categorised as the fine-size fraction and weighed.

Photograph 4 – Sorting the medium-size fraction (30-300mm)

Photograph 5 – Screening the fine-size fraction (<4.75mm) from a mixed C&D load

A-2-3 Sample Validation

Validation and quality control was an important component of the physical audit. The information gained was used to understand the sample errors associated with using a sample based audit strategy (see Appendix D for more detail). Sample validation was undertaken for:

- Sampling of Stockpiles

  The sampling strategy required a single 8-15m^3 sample to be selected from each 100m^3 stockpile for measurement. To understand the variation of sample selection, one stockpile was selected and four 8-15m^3 samples were taken. The compositional analysis of the four samples provided an indicator of the expected variance associated with sample selection.

- Material Classification of the Medium-size Fraction (30-300mm)

  The medium-size fraction for one sample was sorted and re-mixed four times so that the accuracy of the compositional analyses could be recorded and compared. The sample was recombined and put back through the entire sorting process as part of this exercise.

- Material Classification of the Small-size Fraction (4.75-30mm)

  The small-size fraction from one sample was selected for validation sampling. Five composite portions, each consisting of two 20L containers, were removed from the nominated sample and sent to a geotechnical laboratory for analysis.

- Purity Audits

  The contractor was required to conduct random purity audits on sorted and classified waste materials from the medium-size fraction. This was to demonstrate the accuracy of the hand sorting and classification of the waste materials, which was required to be >95% accuracy. The contractor was required to submit documented evidence that random purity audits had been completed for each of the samples analysed.

A-3 Chemical Analysis

Chemical analysis of the fine-size fraction of the mixed C&D waste stream was undertaken, as well as chemical analysis of wood samples that were retained from the audit.

A-3-1 Wood Waste

During the audit, 250 individual wood samples were collected from mixed C&D waste stockpiles. Characteristics of the wood such as source, age and particle-size were collected for each sample.

The samples were prepared using a hammer mill and analysed for a range of chemicals. The results appear in Appendix 2.

A-3-2 Fine Fraction

A 40kg sample of material less than 30mm was collected during the audit from each stockpile. The samples were then sieved on a 4.75mm screen to assist in determining the material components of the small-size fraction. Any material that passes through the 4.75mm sieve has been defined as belonging to the fine-size fraction, which may consist of soil as well as other materials such as plasterboard that has broken down before being received at the landfill. It was hammer milled before chemical analysis.

A wide suite of potential chemicals that may be present in the Fine Fraction (~150 chemicals) was tested to determine the concentrations for each stockpile sample. A summary of the chemical results appear in Appendix B.

A-4 Other Issues and Data Quality

During the course of the audit fieldwork operational issues were identified that had the potential to affect the quality of data collected. Where possible, DECC staff and the contractors conducting the audit work identified and resolved these issues. Some of the predominant issues that became apparent during the audit are described in the following section.

A-4-1 Safety Issues

A-4-1-1 Site Supervision

Some issues were raised and resolved by landfill operators, DECC personnel and the Waste Audit contractor to ensure safety and work method procedures were strictly followed, including the need to use personal protective equipment (PPE) when hand sorting the 30 to 300 mm size fraction, mobile plant isolation procedures and sub-contractor training for access to the landfill sites.

A-4-2 Site Management

A-4-2-1 Ground Surface Sampling

One of the limitations of the audit process was the contamination of the sample stockpiles from the ground surface on which they were built. There was no access to areas of hardstand on which to construct the sample stockpiles. All sites ensured that the audit area ground surface was well compacted, and in some cases site operators laid down areas of crushed rock and brick to increase the stability of the ground surface and further minimise the possibility of contamination.

A sample was removed from the completed stockpiles for analysis by either a bobcat or front-end loader. The plant operators conducting this sampling were extremely careful not to disturb the ground surface when cutting these samples but it should be noted that the precautions used generally had one of two consequences:

1. To leave a small amount of the required sample in situ from running a front-end bucket through the sample just above ground level.
2. To incorporate a small amount of ground surface material in the sample due to uneven ground or running the front-end bucket through the sample just below ground level.

A-4-2-2 Moisture Content

Some minor elements of the audit fieldwork were conducted during periods of rain. It was not possible to cover the stockpiles in these circumstances and moisture ingress may have occurred during the construction of stockpiles.

Although the sample material taken from the stockpiles at each landfill site for analysis varied in moisture content, most of the fine-size fraction had consistently low moisture levels (<5%) due to minimal rainfall during the audit. No additional moisture testing on the concrete or plasterboard material fractions were required due to the minimal rainfall during the audit.

A-4-2-3 Ferrous Metal Recovery Practices

Some of the participating landfill sites employed different resource recovery practices for ferrous metals at the tip face, which were often removed from the tip face by an electro-magnet attached to an excavator. The efficiency of this operation is dependent on the following:

- visibility of the individual items of material in mixed loads of waste
- the diligence of the plant operator
- the amount of time each day that this operation can be conducted.

For these reasons the recovery rates of ferrous metal at different sites on any given day can vary dramatically.

The stockpiles created at landfill sites that employed this method of ferrous metal recovery, were constructed from vehicle loads as they entered the site, prior to disposal. The quantity of ferrous metal disposed is therefore probably slightly overstated. This factor should be taken in to consideration when reviewing the data.

A-4-2-4 Mechanical Plant

Two different types of mechanical sorting/processing plant were used during the audit as two sites were being audited at any one time. These plant items used different mechanical processes for sorting the sample material.

The Doppelstadt trommel uses a rotating drum screen to separate material, whereas the Pitbull plant uses a vibrating flat screen to separate material. These two different processes mean that the particle-size and shape of greater than 30mm particles that passed through different screen sizes varied slightly between the two plant units. The difference is not significant for total stockpile composition, however the composition of the small-size and medium-size fractions may differ slightly.

The Doppelstadt trommel was fitted with raised conveyor belts for the segregation of fine-size particle fraction. During periods of high wind there was a small loss of this fraction as it fell from the raised belt into the skip bin that had been positioned underneath to collect it.

A-4-3 Data Management

A number of minor issues arose with regard to the management of data during the course of the field audit and in some of the post-audit laboratory analyses. These issues were resolved during the audit. These issues were:

(a) Daily reconciliation of data sheets to ensure that all data is captured and that all data sheets are completed correctly and quality checked for errors. This includes, but is not limited to, a daily check and reconciliation of:

- Data sheet totals
- Material codes for each data entry (includes material name and code)
- Completion of all data sheet specific information (site ID, date, sheet number, sub-stream ID, stockpile ID, sample ID, sort number, etc)
- Sample totals (when analysis of a sub-stream or stockpile is completed).

(b) Labelling of all samples collected to ensure that they can all be linked to the stockpiles from which the samples were originally taken.

(c) Chain of custody and sign-off procedure for all samples removed from site to ensure that at all points of transport, analysis and storage the samples can be clearly identified and accounted for.

A-4-4 Data Quality

The challenge with collecting data about C&D waste is the natural variance in particle-size and weight of materials disposed to landfill. This natural variance combined with variance associated with sample surveys was recognised as a potential risk to the reliability and usefulness of the data obtained through the audit.

The material type data collected through the Mixed C&D Waste Audit was subject to differing degrees of variance. The estimates for common materials such as concrete, timber and fine-size particle fraction are considered reliable for the purposes of this report. While estimates for materials less prevalent such as textiles and paper/cardboard are subject to sampling variability too high for practical purposes.

The desktop audit data is considered to be of high reliability because the data relates to the amount of levy to be paid and is subject to an audit process that carries potential penalties for incorrect reporting.

Further analysis of data quality can be found in Appendix D.

The Mixed C&D Waste Audit was undertaken at selected landfill facilities in the SMA. The selected landfills participating in the audit in 2004-05 disposed of 88% of mixed C&D waste and 77% of all waste from C&D sources in the SMA.

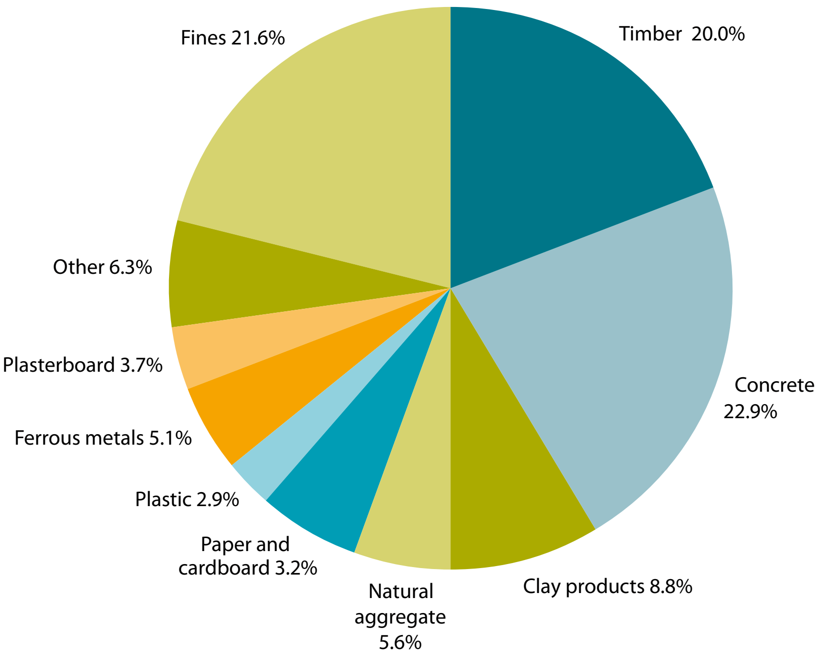
The results of the Mixed C&D Waste Audit show that by weight the main material types of mixed C&D waste are concrete (22.9%), fine-size material (21.6%) and timber (20.0%).

The fine-size fraction is defined as the material less than 4.75mm in size, which was the smallest size fraction that particle composition was undertaken.

Chart 9 below shows the composition by weight of mixed C&D waste. Major material types are presented on the chart with individual material types that comprise less than 3% grouped into the other material type.

Appendix B Mixed C&D Waste Audit Results

Chart 9: Composition of Mixed C&D Waste by weight, 2004-05



Other:

1.8% Garden and vegetation

1.3% Textiles

0.6% Non-ferrous metals

0.4% Glass

0.4% Asphalt

1.8% Miscellaneous

The quantity of mixed C&D waste disposed to landfill in the SMA during 2004-05 was 450,139 tonnes. Applying the results of the composition audit, the quantities of material types comprising mixed waste are shown in Table 6.

Table 6: Estimated quantity of Material Types in Mixed C&D Waste disposed to Landfill in the Sydney Metropolitan Area, 2004-05

Material type	Quantity *tonnes*	Expected range *tonnes*
Concrete	103,000	70,000 – 130,000
Fines (<4.75mm)	97,000	75,000 – 115,000
Timber	90,000	60,000 – 120,000
Clay products	40,000	30,000 – 50,000
Natural aggregate	25,000	20,000 – 30,000
Ferrous metals	23,000	15,000 – 30,000
Plasterboard	17,000	10,000 – 25,000
Paper and cardboard	14,000	5,000 – 25,000
Plastic	13,000	5,000 – 20,000
Garden and vegetation	8,000	5,000 – 15,000
Textiles	6,000	1,000 – 15,000
Non-ferrous metals	3,000	1,000 – 5,000
Glass	2,000	1,000 – 5,000
Asphalt	1,500	1,000 – 2,000
Miscellaneous	8,000	5,000 – 10,000
TOTAL	**450,000**	

Note: Expected range is at a 90% confidence. For example, we are 90% confident that the true quantity of concrete in mixed C&D waste is within the range of 70,000 to 130,000 tonnes.

From Table 6, the main material types disposed of as mixed C&D waste are:

1. concrete (103,000 tonnes)
2. fine-size fraction (97,000 tonnes)
3. timber (90,000 tonnes).

There is the potential that some of these materials disposed to landfill as mixed C&D waste could be recovered for re-use or reprocessing. To understand how this material could be recovered, it was important to characterise how this waste was presenting at landfill. The three main steps undertaken to characterise the waste were:

1. Particle Fraction Analysis
2. Source Flow Analysis
3. Chemical Analysis (on selected material types).

B-1 Particle Size Analysis

As stated in section 3.2.2, the Mixed C&D Waste Audit involved sorting, weighing and classifying material according to particle size. The particle size composition provides information on the potential processes such as screening and sorting technologies that could be used to recover materials.

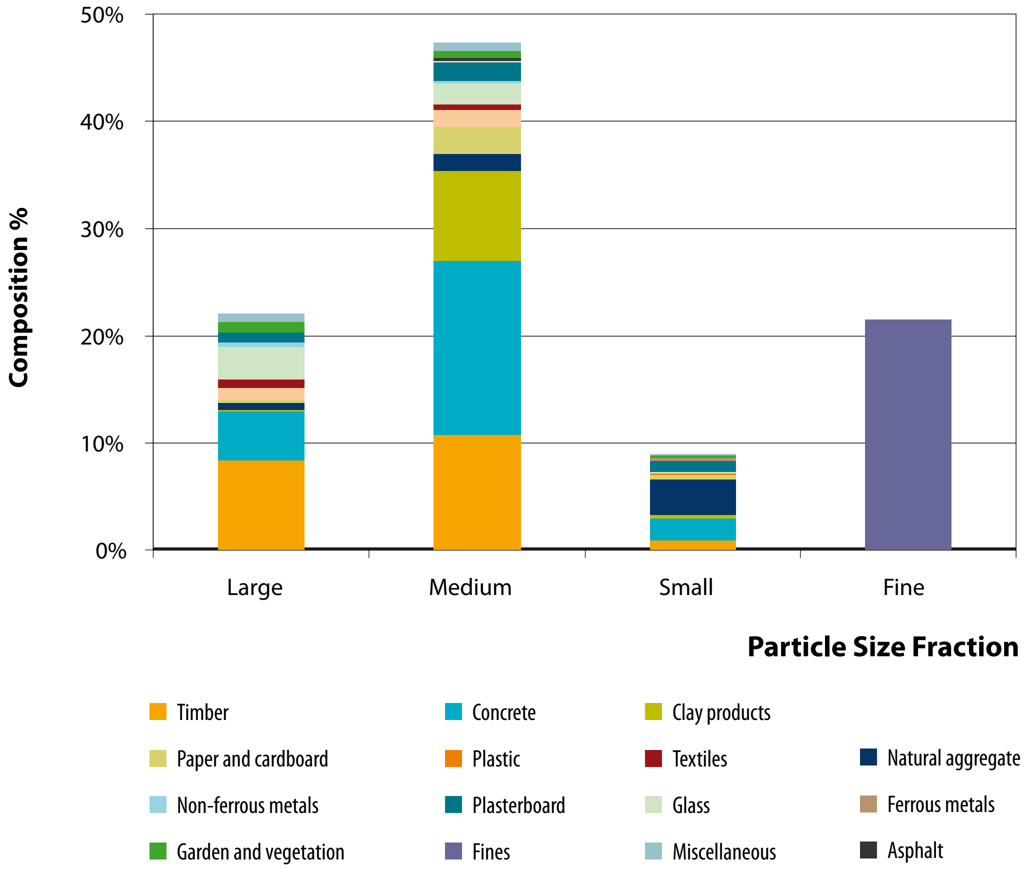
The particle size groupings for the audit were;

- greater than 300mm (large)
- 30mm to 300mm (medium)
- 4.75 to 30mm (small)
- less than 4.75mm (fine).

The medium-size particle fraction was the predominant fraction with 47% of material falling within this range, followed by the large-size particle fraction (22%), the fine-size particle fraction (22%) and the small-size particle fraction (9%).

Chart 10 shows the relative composition of each size fraction by material type.

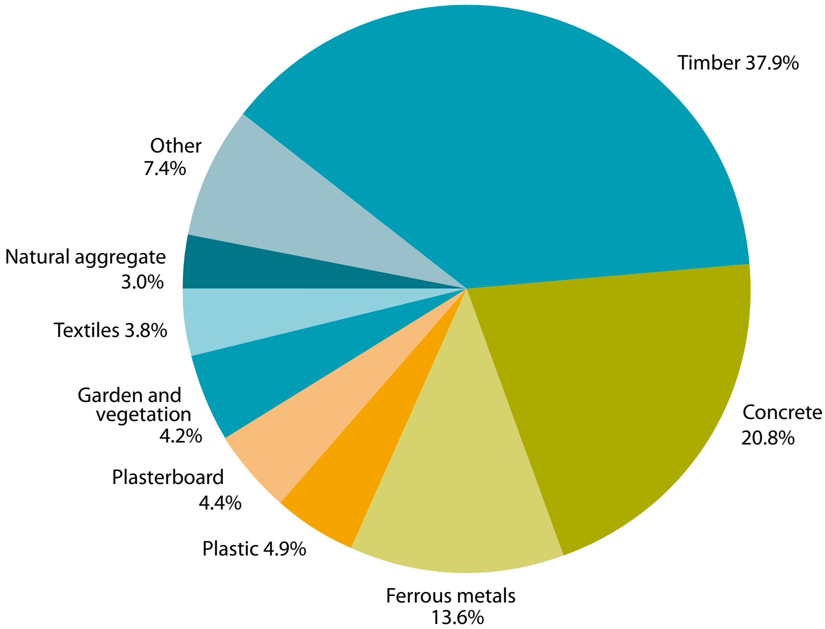
Chart 10: Relative Composition of Mixed C&D Waste by Particle Size and Material Type by weight, 2004-05



B-1-1 Large-size Particle Fraction

Within the large-size particle fraction (>300mm) the main material is timber (37.9%). For this size fraction timber was further categorised into hardwoods 14%, softwoods 14% and other timber 9% (including plywood, MDF and particleboard).

Chart 11: Composition of Mixed C&D Waste Large-size Particle Fraction by weight, 2004-05



Timber:

14.4% Hardwood

14.4% Softwood

9.1% Other (plywood, MDF and particleboard)

Other:

1.9% Non-ferrous metals

1.3% Paper and cardboard

0.6% Clay products

3.5% Miscellaneous

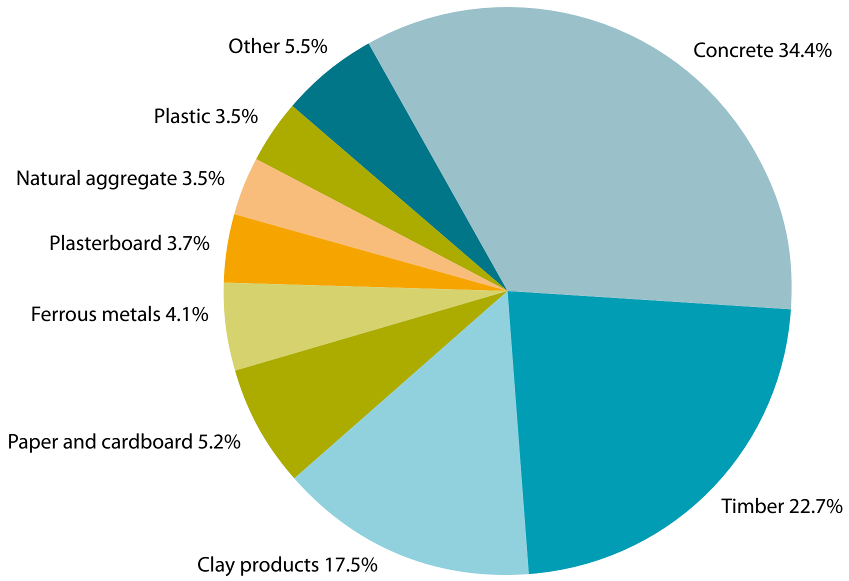
Table 7: Estimated quantity of Mixed C&D Waste Disposed to Landfill in the Large-size Particle Fraction, 2004-05

Material type	Quantity *Tonnes*
Timber Hardwood *14,000* Softwood *14,000* Other *9,000*	38,000
Concrete	21,000
Ferrous metals	13,000
Plastic	5,000
Plasterboard	4,000
Garden and vegetation	4,000
Textiles	4,000
Natural aggregate	3,000
Other	7,000
TOTAL	**99,000**

B-1-2 Medium-size Particle Fraction

Within the medium-size particle fraction (30mm to 300mm) the main material is concrete (34.4%) followed by timber (22.7%) and clay products (17.5%).

Chart 12: Composition of Mixed C&D Waste Medium-size Particle Fraction by weight, 2004-05



Other:

1.3% Garden and vegetation

1.0% Textiles

0.7% Asphalt

0.4% Non-ferrous metals

0.3% Glass

1.7% Miscellaneous

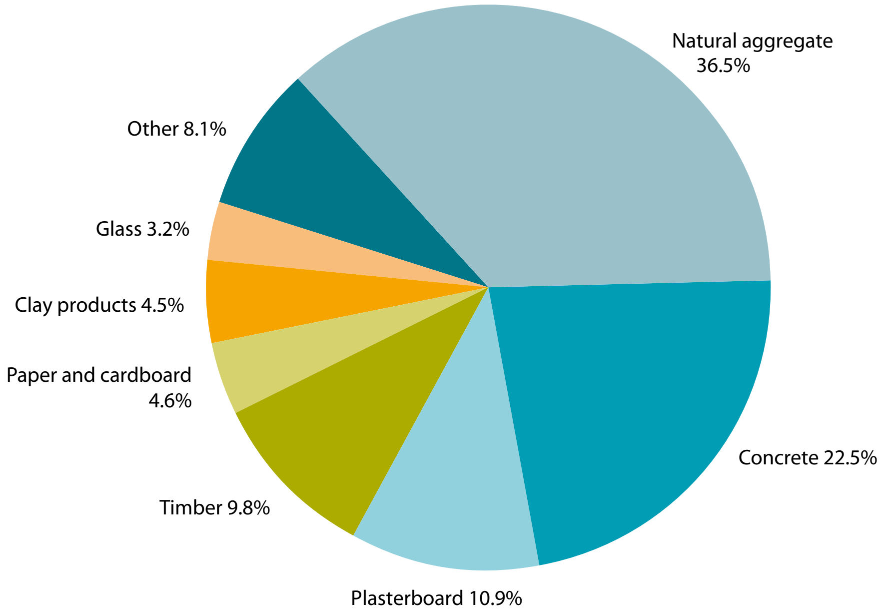
Table 8: Estimated quantity of Mixed C&D Waste Disposed to Landfill in the Medium-size Particle Fraction, 2004-05

Material type	Quantity tonnes
Concrete	73,000
Timber	48,000
Clay products	37,000
Paper and cardboard	11,000
Ferrous metals	9,000
Plasterboard	8,000
Natural aggregate	7,000
Plastic	7,000
Other	12,000
TOTAL	**213,000**

B-1-3 Small-size Particle Fraction

Within the small-size particle fraction (4.75mm to 30mm) the main material is natural aggregates (36.5%) followed by concrete (22.5%) and plasterboard (10.9%).

Chart 13: Composition of Mixed C&D Waste Small-size Particle Fraction by weight, 2004-05



Other:

2.1% Garden and vegetation

1.9% Plastic

1.5% Ferrous metals

0.5% Asphalt

0.2% Textiles

0.1% Non-ferrous metals

1.9% Miscellaneous

Table 9: Estimated quantity of Mixed C&D Waste Disposed to Landfill in the Small-size Particle Fraction, 2004-05

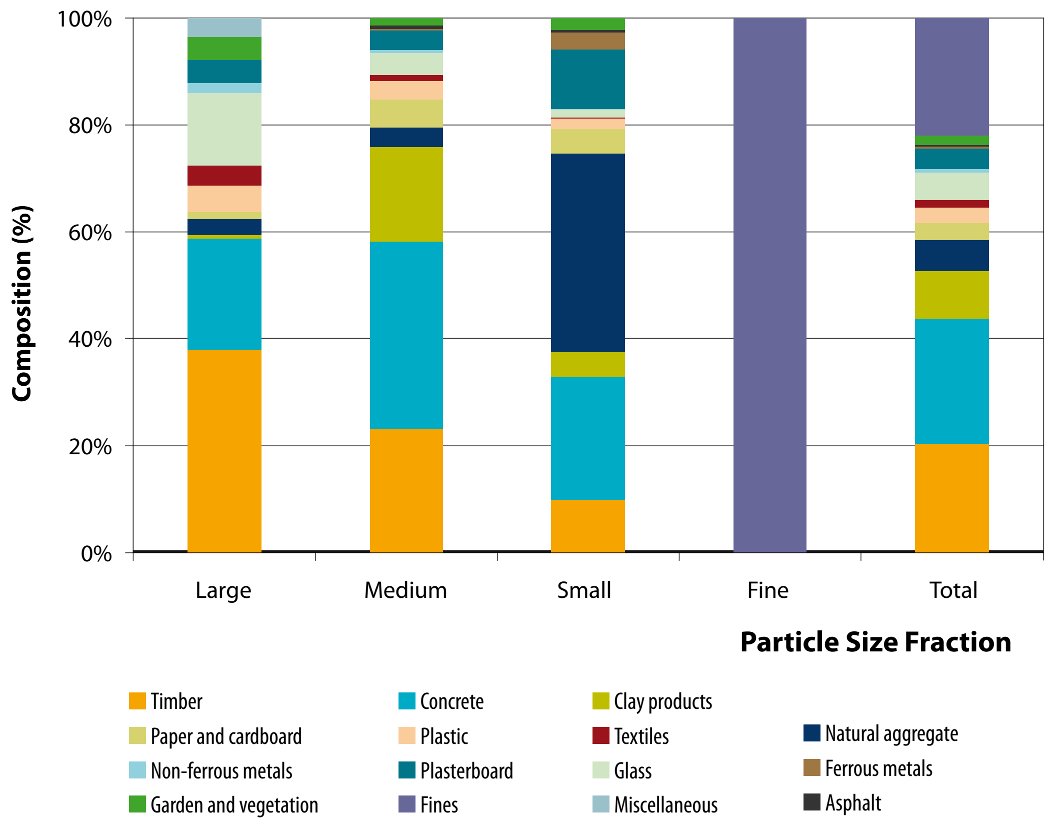
Material type	Quantity *tonnes*
Natural aggregate	15,000
Concrete	9,000
Plasterboard	4,000
Timber	4,000
Paper and cardboard	2,000
Clay products	2,000
Glass	1,000
Other	3,000
TOTAL	**40,000**

B-1-4 Fine-size particle fraction

All material in the <4.75mm size particle fraction was classified as Fine. This fraction comprised 21.6% of mixed C&D waste (97,000 tonnes).

Chart 14 shows the composition of the four particle size fractions and the total composition of mixed C&D waste.

Chart 14: Composition of Mixed C&D Waste by Particle Size Fraction by weight, 2004-05



B-2 Source–Flow Analysis

The Mixed C&D Waste Audit involved identifying the source-flow of mixed C&D waste disposed to landfills. The source-flow analysis provides information on type of material that could be expected by the vehicle that delivers the waste to the landfill.

Three broad source-flows were identified after discussions with landfill operators for the audit, these were;

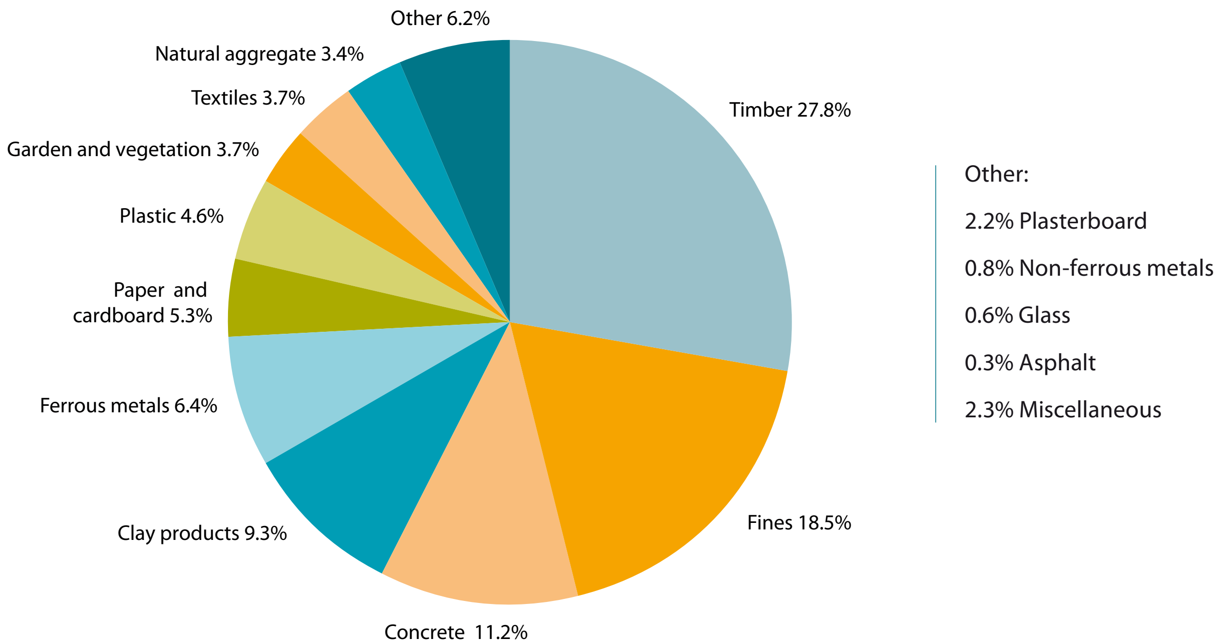
- vehicles from Material Reprocessing Facilities (MRF)
- small vehicles (under $10m^3$, including skip bins)
- large vehicles.

The main flow for transporting mixed C&D waste to landfill was the small vehicles (42%), followed by MRF vehicles (30%) and large vehicles (27%).

B-2-1 MRF Vehicle Source-flow

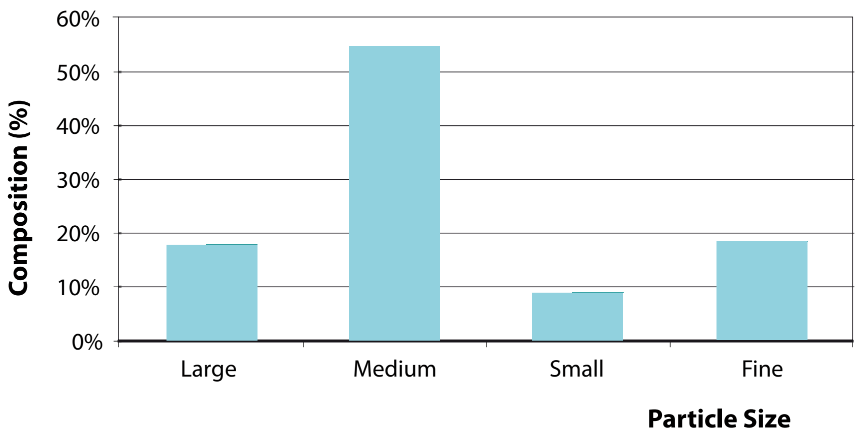
MRF vehicle source-flows account for 30.4% of mixed C&D waste disposed to landfill. The main material types transported to landfill from this flow are timber (27.8%) followed by fines from mixed C&D waste (18.5%) and concrete (11.2%).

Chart 15: Composition of Mixed C&D Waste Disposed to Landfill from MRF vehicles by weight, 2004-05



The predominant particle size in the MRF vehicle source-flow is the medium-size fraction (54.7%), followed by the fine-size fraction (18.5%), the large-size fraction (17.9%) and the small-size fraction (8.9%).

Chart 16: Size Fraction Proportions of Mixed C&D Waste Disposed to Landfill from MRF vehicles by weight, 2004-05

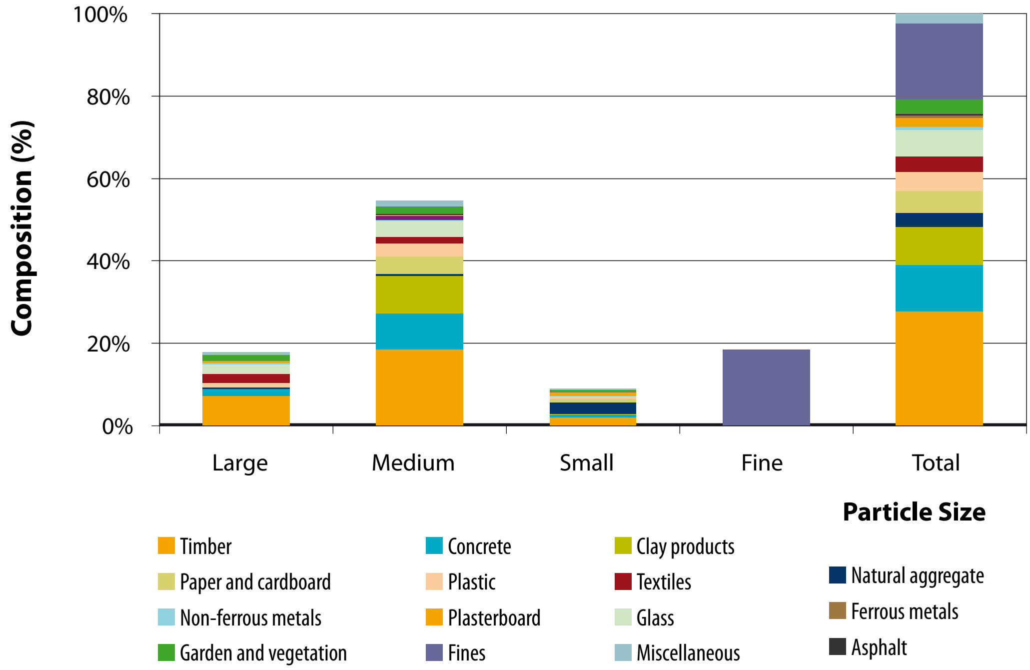


The major material type received in MRF vehicles of mixed C&D waste is timber, most of which is received in the medium-size fraction. Concrete and clay products are other main material types received, the majority of which is within this size fraction.

Fine material from mixed C&D waste was also a major material type in MRF vehicles (by definition all material in the fine-size particle fraction was categorised as 'Fines').

The composition of material received from MRF vehicles by size fraction is shown in Chart 17.

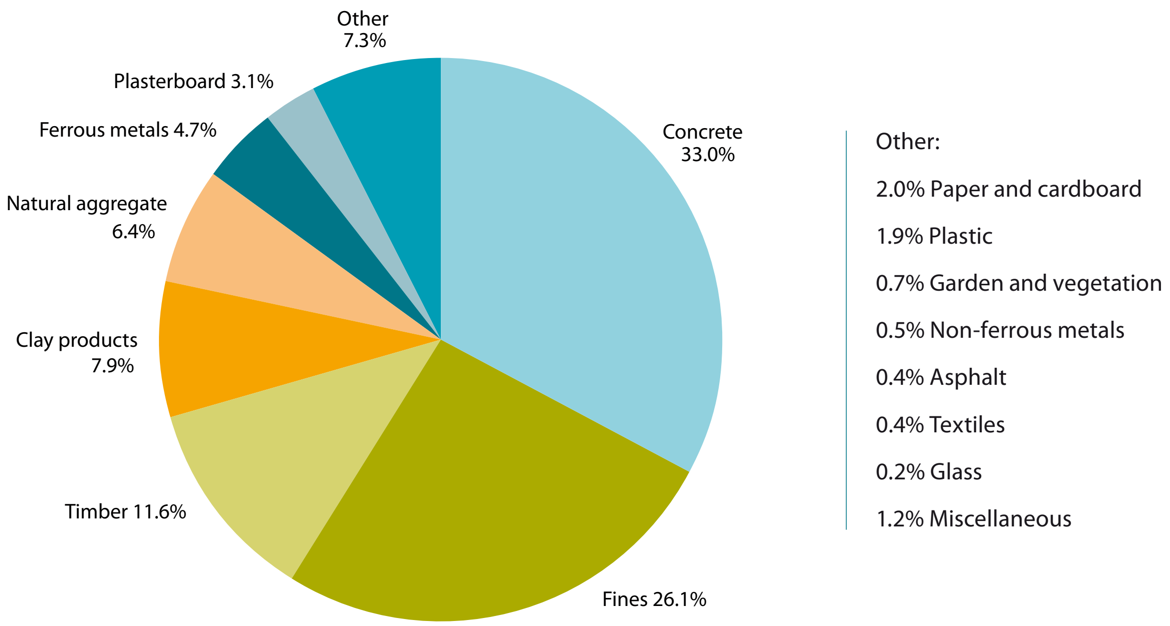
Chart 17: Composition by Size Fraction of Mixed C&D Waste Disposed to Landfill from MRF vehicles by weight, 2004-05



B-2-2 Small Vehicle Source-flow

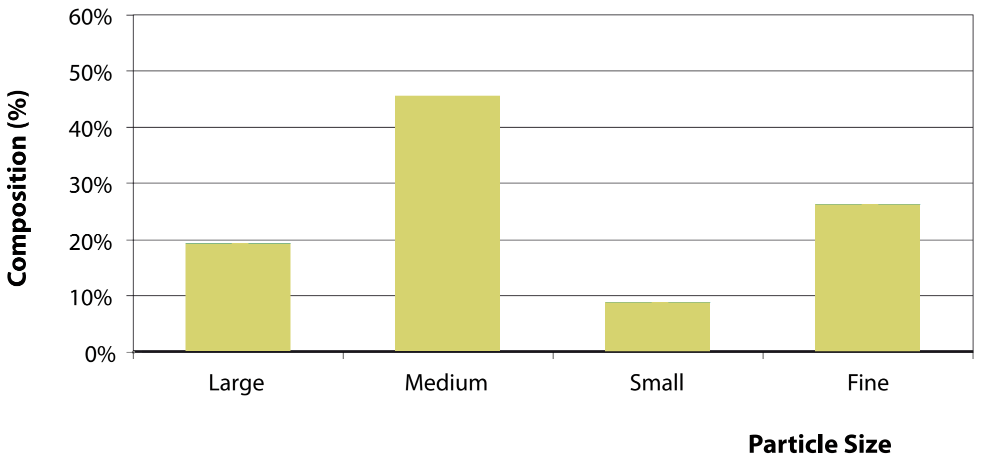
Small vehicle source-flows account for 42.3% of mixed C&D waste disposed to landfill. The main material types transported to landfill from this flow are concrete (33.0%) followed by fines from mixed C&D waste (26.1%) and timber (11.6%).

Chart 18: Composition of Mixed C&D Waste Disposed to Landfill from Small vehicles by weight, 2004-05



The predominant particle size in the small vehicle source-flow is the medium-size fraction (45.6%), followed by the fine-size fraction (26.1%), the large-size fraction (19.4%) and the small-size fraction (8.9%).

Chart 19: Size Fraction Proportions of Mixed C&D Waste Disposed to Landfill from Small vehicles by weight, 2004-05

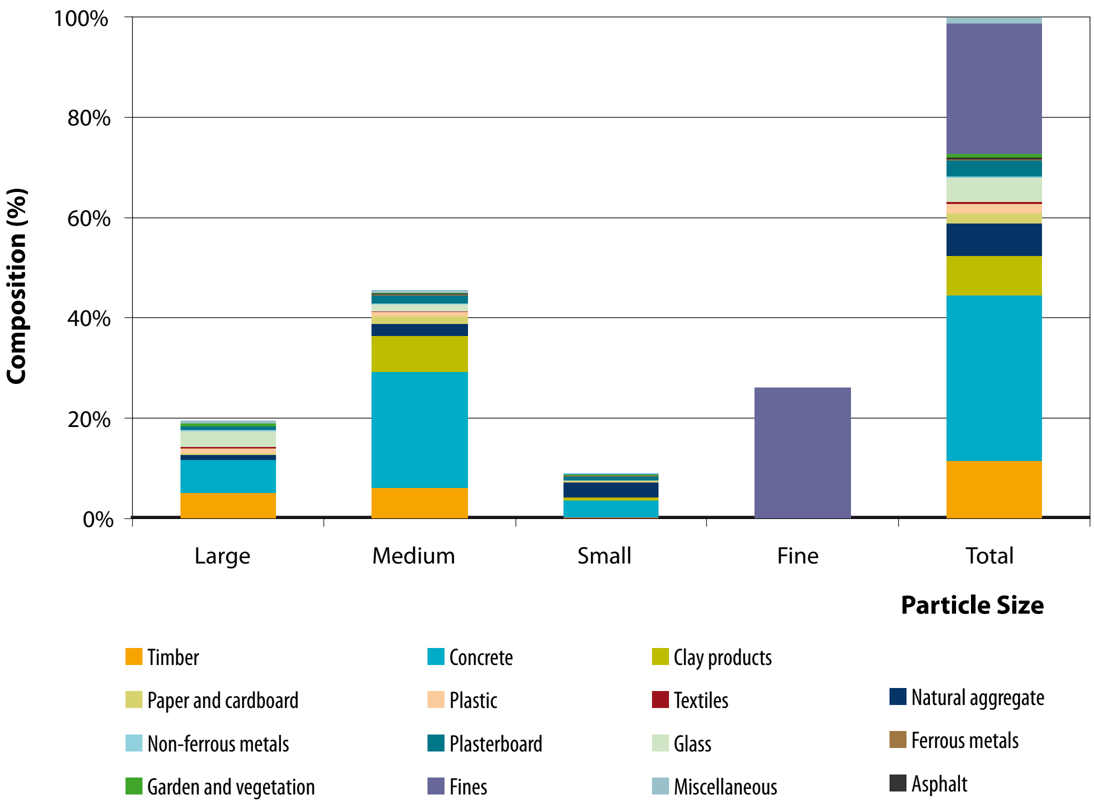


The major material type received in small vehicles of mixed C&D waste is concrete, most of which is received in the medium-size fraction. Timber and clay products are other main material types received, the majority of which is within this size fraction.

Fine material from mixed C&D waste was also a major material type in small vehicles (by definition all material in the fine-size particle fraction was categorised as 'Fines').

The composition of material received from small vehicles by size fraction is shown below in Chart 20.

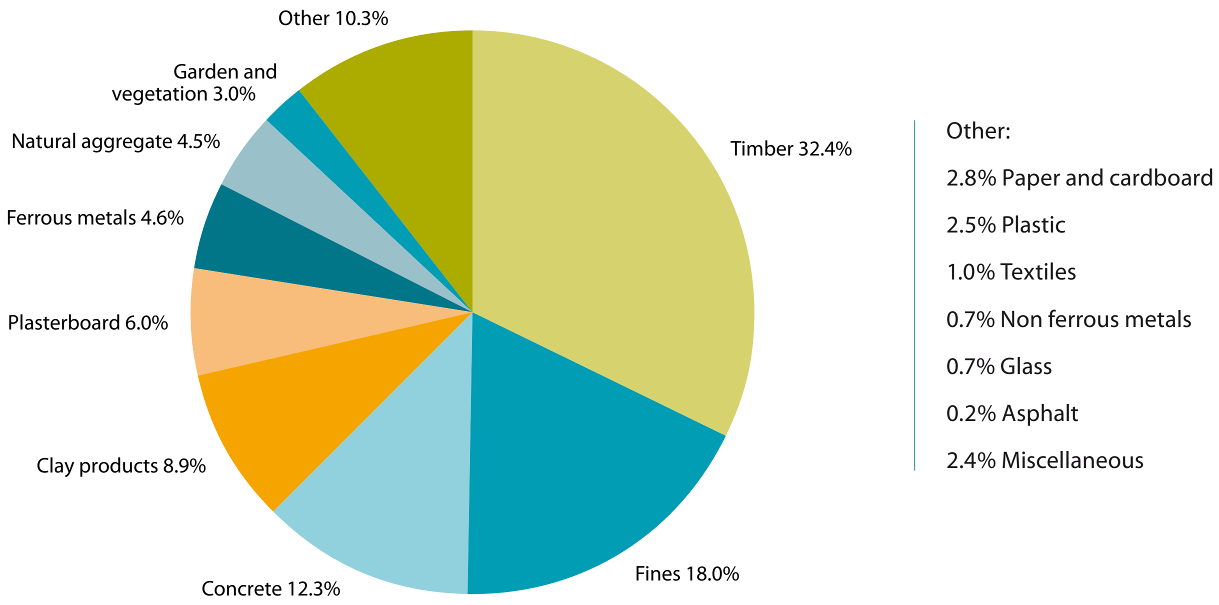
Chart 20: Composition by Size Fraction of Mixed C&D Waste Disposed to Landfill from Small vehicles by weight, 2004-05



B-2-3 Large Vehicle Source-flow

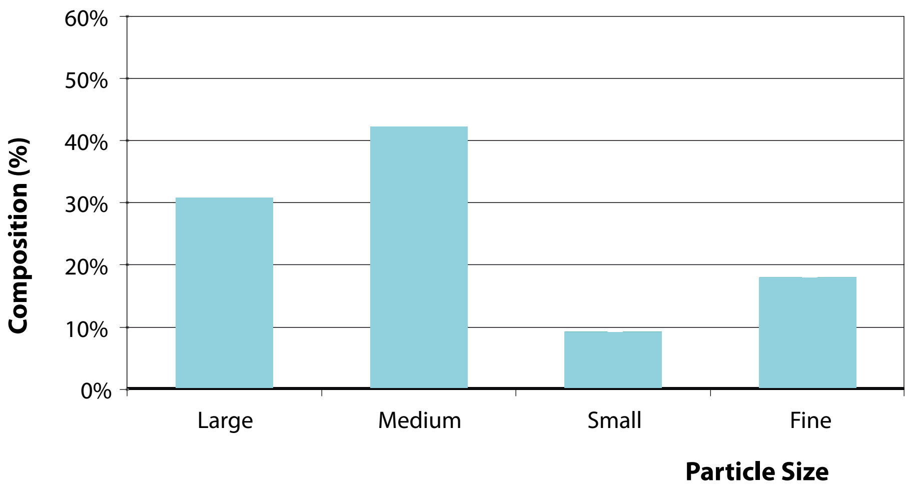
Large vehicle source-flows account for 27.3% of mixed C&D waste disposed to landfill. The main material types transported to landfill within this flow are timber (32.4%) followed by fines from mixed C&D waste (18.0%) and concrete (12.3%).

Chart 21: Composition of Mixed C&D Waste Disposed to Landfill from Large vehicles by weight, 2004-05



The predominant particle size in the large vehicle source-flow is the medium-size fraction (42.1%), followed by the large-size fraction (30.7%), the fine-size fraction (18.0%) and the small-size fraction (9.2%).

Chart 22: Size Fraction Proportions of Mixed C&D Waste Disposed to Landfill from Large vehicles by weight, 2004-05

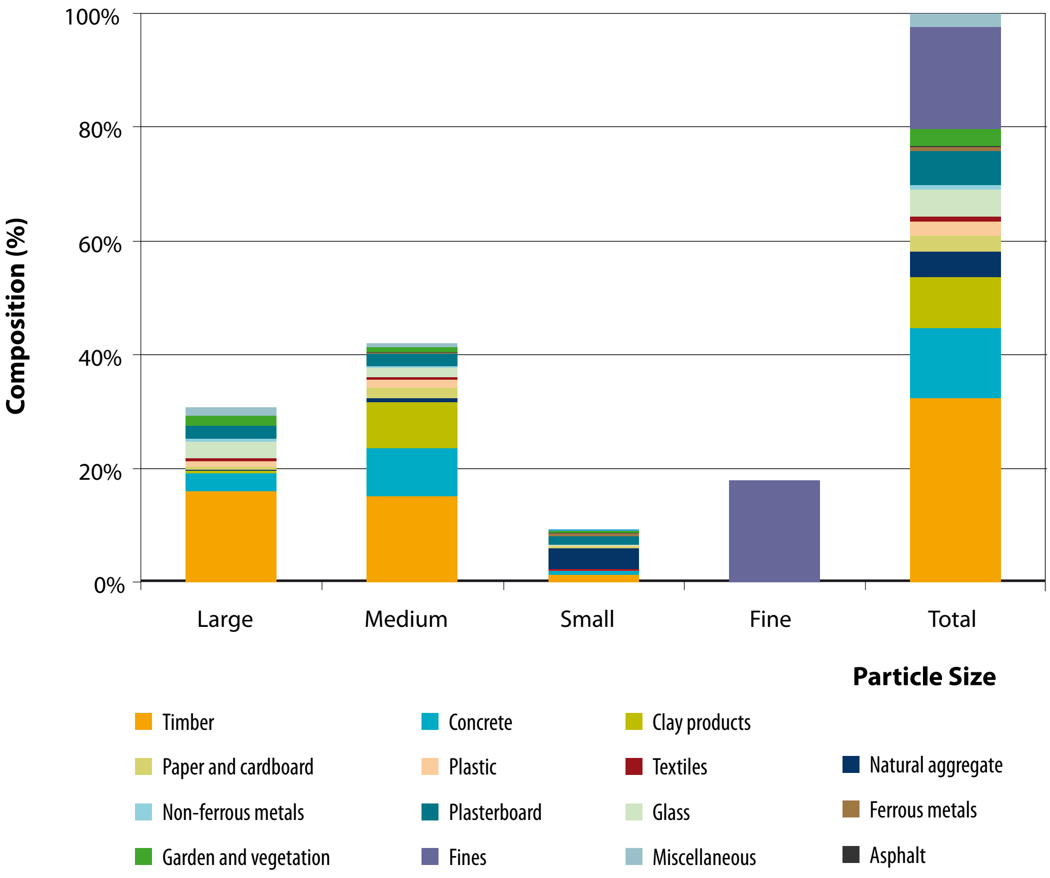


The major material type received in large vehicles of mixed C&D waste is timber, most of which is received in the large-size fraction. Concrete and clay products are other main material types received, the majority of which is within the medium-size fraction.

Fine material from mixed C&D waste was also a major material type in large vehicles (by definition all material in the fine-size particle fraction was categorised as 'Fines').

The composition of material received from large vehicles by size fraction is shown below in Chart 23.

Chart 23: Composition by Particle-size Fraction of Mixed C&D Waste Disposed to Landfill from Large vehicles by weight, 2004-05



B-3 Source-flow by Material Type

The analysis of source-flow of mixed C&D waste to landfill by material type shows by vehicle type which materials are likely to be present for recovery processes.

For example, if a facility was targeting the recovery of concrete products from mixed C&D waste, then small vehicles (less than 10m^3, including skip bins) are likely to have a relative large proportion of concrete products (33.0%) and could be directed to a stockpile for sorting.

Likewise, for recovery of timber, large vehicles (32.4%) and vehicles from MRFs (27.8%) have relative high proportions of timber.

Table 3 shows the composition of mixed C&D waste by source flow and total.

B-4 Chemical Analysis

B-4-1 Wood Waste

There are three distinct patterns that can be identified from the chemical analyses.

B-4-1-1 Treated Timber

The vast majority of the wood waste samples had very low levels of copper, chromium and arsenic, however a small proportion of the samples (~ 4%) had very high levels (> 1000 mg/kg). One potential cause of this evident dichotomy could be the timber treatment based on 'CCA', which is more prevalent in softwood that has recently been generated as waste during construction activities.

The very high chemical levels of copper, chromium and arsenic (CCA) present in treated timber can impact on the quality of wood waste recovered for recycling. One piece of CCA treated timber (1,000 to 3,000 mg/kg of copper, chromium or arsenic) can significantly alter the average concentration of a batch of waste wood, which would otherwise contain very low natural background levels (1 to 3 mg/kg). Charts 24 and 25 highlight this effect.

Chart 24: Distribution Graph of CCA Contaminants in Mixed C&D waste timber from Field Audit

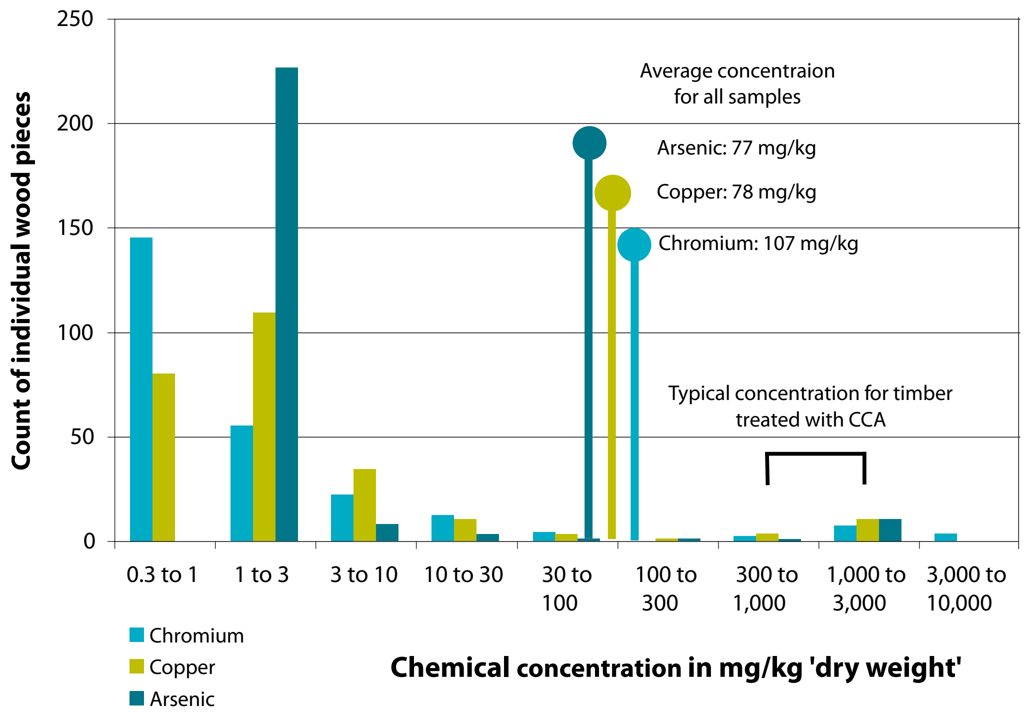
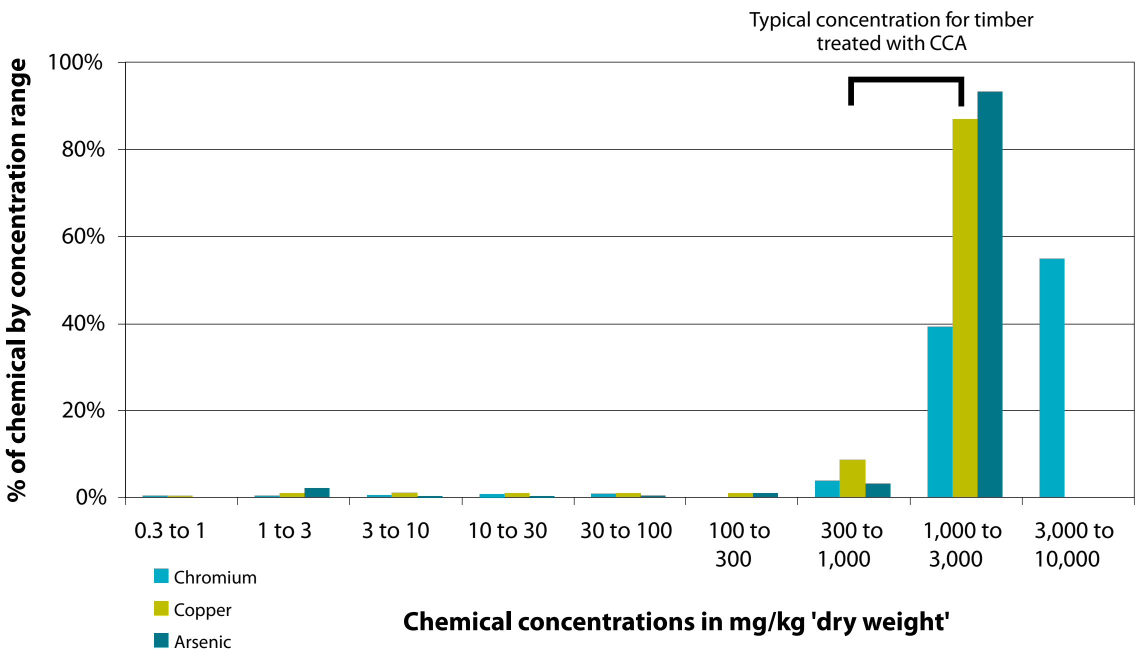


Chart 25: Estimated Distribution of CCA in Mixed C&D timber waste



B-4-1-2 Paint and Varnish

The lead, zinc and mercury concentrations of the sampled wood waste appear to be related to the presence of paint or varnish on the surface of the individual samples. A less distinct relationship occurs for cadmium. Additionally, most of the samples that have high concentrations of lead, cadmium and zinc are sourced from demolition waste. Table 10 presents average concentrations for a number of criteria such as source, type of wood and age of the wood waste.

Waste wood that has been processed to recover recyclable materials (i.e. sourced from MRF vehicles) appear to have relatively low lead, zinc and cadmium concentrations. This may be a result of the physical removal or breaking down of the paint or varnish film during processing at a C&D MRF. The chipped off paint and varnish may concentrate in the fine-size fraction from mixed C&D waste or dust generated when the affected timber is processed.

From the chemical analysis about 2% of timber samples contained levels of lead that would be inappropriate for re-use or recovery.

Table 10: Average Concentration by Criteria (mg/kg 'dry weight')

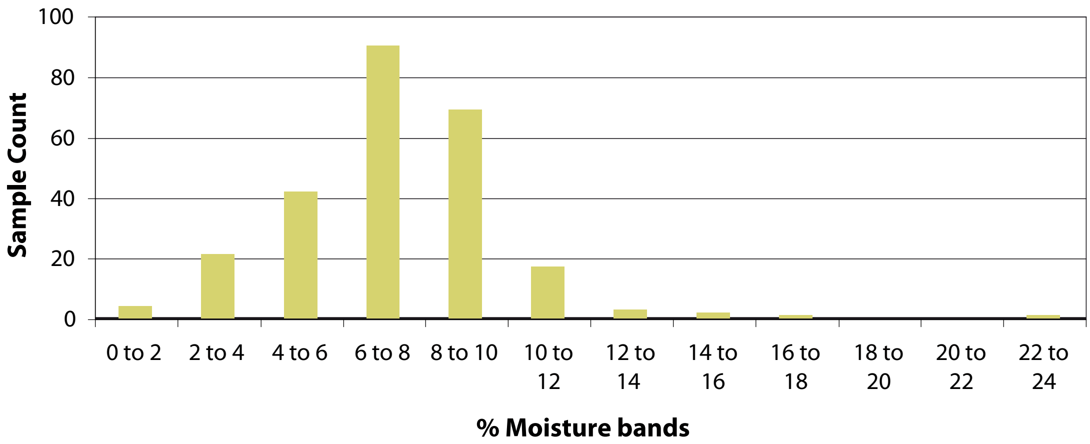
Criteria	No. of samples	Lead	Zinc	Mercury	Cadmium
Hardwood	52	116	69	0.07	0.28
Softwood	157	136	256	0.18	0.27
Construction (new wood)	72	4	12	0.06	0.29
Demolition (old wood)	178	154	245	0.17	0.39
Painted wood	25	688	1100	0.55	0.25
Varnished wood	7	26	1250	0.29	3.46
MRF vehicle source	120	41	29	0.07	0.27
Large vehicle source	59	88	331	0.15	0.64
Small vehicle source	71	248	301	0.25	0.29
All samples	250	111	178	0.14	0.36

B-4-1-3 Natural Background Levels

The concentration of iron and manganese appear to be fairly constant across all samples of wood waste. There are some small differences in background levels of iron and manganese between softwood and hardwood. Hardwoods appear to contain a high natural background level of iron, while manganese is concentrated in softwoods.

The moisture levels were fairly consistent, with an average of about 7%: 80% of samples have between 4% and 10% moisture content. The distribution of moisture levels is presented in Chart 26.

Chart 26: Moisture levels of Waste Wood in Construction and Demolition Waste



B-4-2 Recovery of Wood Waste

The potentially recoverable timber from mixed C&D waste is currently about 6,000 tonnes per month for the SMA. As CCA treated timber is more likely to present as waste in the future, the amount potentially recoverable may decline significantly. Estimated quantities of recoverable timber are shown in Table 11.

An estimate of the non-recoverable quantity of C&D waste timber of 18,000 tonnes pa is based on the amount disposed of in the small-size fraction (4,000 tonnes pa), the 8,600 tonnes pa lost during processing and 5,200 tonnes pa of chemically contaminated timber.

Table 11: Estimated Quantities of Recoverable Timber by Particle Size in the SMA

Particle Size	Flow of timber for disposal from mixed C&D waste.	Minus ~ 4 % CCA treated timber.	Minus ~ 2 % timber with lead paint.	Minus ~ 10 % for screening and size reduction losses.[5]	Potentially recoverable timber.
	tonnes pa	*tonnes pa*	*tonnes pa*	*tonnes pa*	*tonnes pa*
Large (> 300mm)	38,000	-1,520	-760	-3,800	31,920
Medium (30-300mm)	48,000	-1,920	-960	-4,800	40,320
TOTAL	**86,000**	**-3,440**	**-1,720**	**-8,600**	**72,240**

5 The mechanical sorting of wood waste, as evident during the Audit, causes particle-size breakdown resulting in large and medium-size fraction losses to the small-size particle fraction. A 10% processing loss is a reasonable estimate.

B-4-3 Fine-size Fraction from Mixed C&D Waste

A number of chemicals were detected at levels in the fine-size fraction of mixed C&D waste that may potentially limit the appropriate recycling and re-use in an environmentally suitable manner. These chemicals are discussed below.

- **Lead**
  Total lead levels (mg/kg 'as received') in the fine-size fraction were consistently high from all sources. However small vehicles had more than four times the concentration found in either large vehicles or MRF vehicles (~950mg/kg compared with ~200mg/kg) . The high lead levels could be related to demolition and renovation waste material that contain lead-based paints or lead-containing dusts or soils.
- **Sulphate**
  Again, reasonably high levels of sulphate were found in the fine-size fraction regardless of source flow. Typically the range was 6,000 to 12,000 mg/kg. The maximum observed level was 20,000 mg/kg in one MRF vehicle sample. The small-size fraction of the same sample had 1.7% plasterboard, so it is likely that the high sulphate level is due to plasterboard.
- **Hydrocarbons C15-C28 & C29-C36**
  Most samples taken from the fine-size fraction had levels of hydrocarbons between 100 and 500 mg/kg, although a small number of samples had substantially higher levels (1,300 to 3,300 mg/kg).
- **Benzo(a)anthracene**
  The typical level within the fine-size fraction ranged between 0.1 and 0.5 mg/kg, although a number of samples had levels of 1.0, 1.6 and 7.6 mg/kg.
- **PAHs (Polycyclic Aromatic Hydrocarbons)**
  Low levels of a range of PAHs were found. Average concentrations for Benzo(b)fluoranthene, Fluoranthene and Pyrene in the range 1 to 2mg/kg.
- **Bis-2-ethyl hexyl phthalate**
  The typical level within the fine-size fraction ranged between 1 and 5 mg/kg although three of samples exhibited levels 10 times higher at 21, 32 and 38 mg/kg. These 'spikes' in concentration occurred across all three source streams – large, small and MRF vehicles.
- **Pesticides**
  One sample, sourced from MRF vehicles had a total of 3.6 mg/kg of the pesticides DDD, DDE and DDT. A different sample, sourced from a large vehicle had 0.2 mg/kg of Chlordane. Other pesticide levels were lower than the detection limits of the analytical test method.

The results of other chemical analysis, which do not affect the appropriate recycling of C&D waste may be of interest for minimising total waste-management costs. Drying out or 'pre-treating' waste may lower the environmental impact of waste disposed to landfill but there would appear to be little benefit derived from drying Fines from mixed C&D waste before disposal. Most samples had < 5% moisture, with only 3 samples having between 5% and 10% moisture.

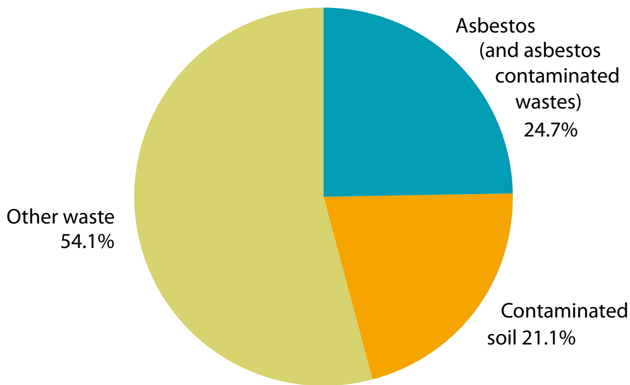
Appendix C: C&D Waste Flows from Monthly Reported Landfill Returns

C&D waste disposed to landfill in the SMA can be characterised into three main categories:

1. **Asbestos:** asbestos and asbestos-contaminated material required to be disposed to landfill. Asbestos contaminated-soil is the primary component.
2. **Contaminated soil:** soil that has contaminants (excluding asbestos) at levels considered 'solid' or 'industrial' according to the NSW Waste Classification Guidelines and for which there are very limited environmentally appropriate recycling or re-use options.
3. **Other waste:** is the balance of materials, much of which is mixed C&D waste generated by the construction and demolition industry as well as residual materials from which material of value that can be reprocessed or recycled has been removed.

Chart 27 below shows the material composition of C&D waste disposed to landfill in the SMA for the 2004-05 financial year. The data is sourced from the Waste Contribution Monthly Reports submitted to the Department of Environment and Conservation NSW by licensed landfills under *Section 88 of the Protection of the Environment Operations Act 1997*.

Chart 27: Composition of C&D Waste Disposed to Landfill in the Sydney Metropolitan Area, 2004-05



The *Waste Avoidance and Resource Recovery Strategy, 2003*, has set the target for the recovery and use of secondary resources from the C&D waste stream at 76% by 2014.

From the *Waste Avoidance and Resource Recovery – A Progress Report, 2004*, the recovery and use of secondary resources rate for C&D waste was reported at 75%.

The composition of C&D waste disposed to landfill as shown in Chart 1 indicates the there is currently very limited opportunity to appropriately recover 46% (contaminated soil 21.1% and asbestos 24.7%) of this material. Therefore, future improvements for recovery of C&D waste will come from the ability to recover material from the other waste component. It also needs to be understood that a significant portion of other waste has already been sorted repeatedly to extract valuable material.

To identify the potential for further recovery of secondary resources from the other waste currently disposed to landfill it is important to consider the monthly flow and quantity of this material. From January 2000 to June 2005 the average monthly quantity of C&D waste disposed to landfill has been 96,000 tonnes with other waste comprising 63%.

In the 2004-05 financial year the average monthly quantity of C&D waste disposed to landfill has been 109,000 tonnes with other waste comprising 54%.

Table 12 shows the monthly average disposal of the C&D waste by material type.

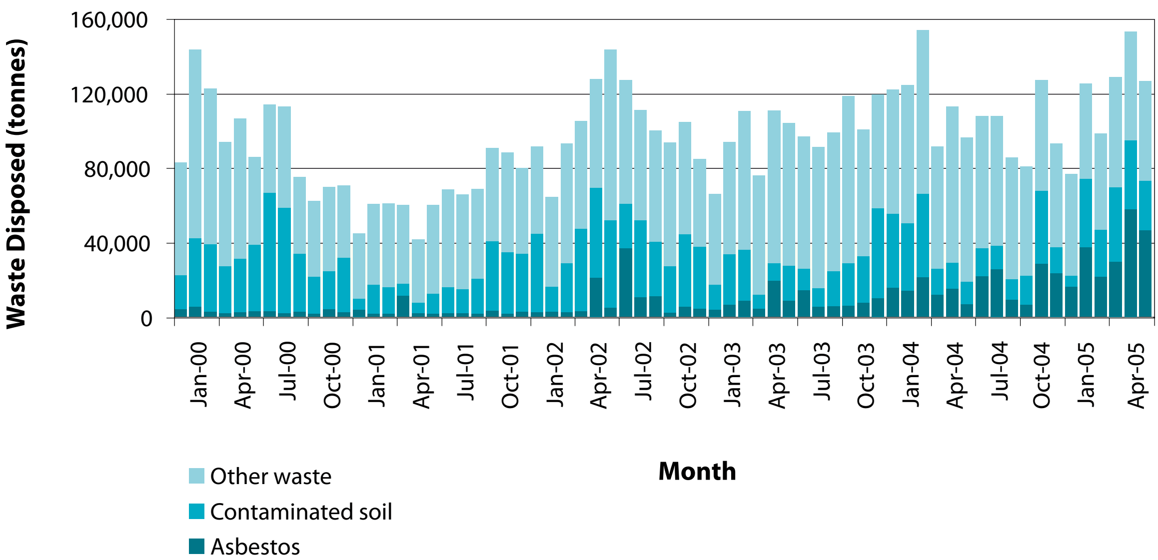
Table 12: Average Monthly C&D Waste Disposed by Material Type in the Sydney Metropolitan Area

Period	Material type			
	Other waste	Asbestos *(and asbestos contaminated waste)*	Contaminated soil	**Total**
	average tonnes per month			
January 2000 to June 2005	60,000 (63%)	10,000 (10%)	26,000 (27%)	**96,000**
July 2004 to June 2005	59,000 (54%)	27,000 (25%)	23,000 (21%)	**109,000**

From Table 12, the composition of C&D waste disposed to landfill is changing as increased quantities of asbestos and asbestos-contaminated material are being disposed. Increasing rates of asbestos disposal minimises the potential of environmental harm by removing waste asbestos from residential areas into controlled landfill facilities. The actual quantities of other waste and contaminated soil have remained relatively stable when expressed as monthly averages.

Chart 2 shows the actual quantity of each C&D waste category disposed to landfill each month from January 2000 to June 2005. The quantity of other waste disposed is relatively consistent whereas contaminated soil is more volatile and asbestos is trending upwards.

Chart 28: Quantity of C&D Waste Disposed to Landfill by Material Type in the Sydney Metropolitan Area, January 2000 to June 2005



Asbestos and contaminated soil (for which there is little to no opportunity for recovery) comprise 46% of the C&D waste disposed to landfill. The question becomes what comprises the remaining category (known as other waste) and are there further opportunities for resource recovery from this 54% component.

The current recovery rates of material sent to landfill for disposal can be established from the Waste Contribution Monthly Reports data maintained and analysed by the Department of Environment and Conservation. Table 2 shows the recovery of materials received at landfill based on the monthly reports by landfillers.

From Table 2, the 'mixed' waste material type is the single largest material disposed to landfill from C&D sources. As stated in section 2.1, to understand the composition of mixed waste an audit was undertaken of the major landfills disposing of mixed C&D waste in the SMA.

It is possible to conclude from Table 13 that there are quantities of bricks and concrete and soil disposed to landfill that could potentially be recovered. However, the reality is that a quantity of this material is required by the landfill operators for the safe operation of the landfill.

Table 13: Recovery of C&D Waste by Material Type from Landfill in the Sydney Metropolitan Area, 2004-05

Material type	Received tonnes	Disposed tonnes	Recovery Rate (%)
Asbestos (and asbestos contaminated wastes)	320,000	320,000	0%
Contaminated soil	280,000	280,000	0%
Aggregate, road-base and ballast	31,000	3,000	90%
Bricks and concrete	490,000	110,000	78%
Compost	17,000	17,000	0%
Ferrous metals	1,000	0	100%
Mixed waste	500,000	450,000	10%
Plasterboard	1,000	1,000	0%
Residuals or rejects	8,000	8,000	0%
Soil	320,000	110,000	66%
Vegetation and garden	17,000	1,000	94%
Wood, trees or timber	11,000	3,000	73%
TOTAL[6]	**2,000,000**	**1,300,000**	**35%**

Note that the three broad categories used to characterise C&D waste have been compiled as such:

- Asbestos is comprised of asbestos material type only
- Contaminated soil is comprised of contaminated soil material type only
- Other waste is the balance of materials.

Table 14 below shows the quantity of material listed as disposed in Table 14 that is actually used on the landfill for operational purposes.

Table 14: Quantity of C&D Waste used as Operational Purpose by Landfills in the Sydney Metropolitan Area, 2004-05

Material type	Disposed tonnes	Operational Purpose tonnes
Asbestos	320,000	0
Contaminated soil	280,000	30,000
Aggregate, road-base and ballast	3,000	2,000
Bricks and concrete	110,000	75,000
Compost	17,000	0
Mixed waste	450,000	30,000
Plasterboard	1,000	1,000
Residuals or rejects	8,000	0
Soil	110,000	30,000
Vegetation and garden	1,000	0
Wood, trees or timber	3,000	0
TOTAL[6]	**1,300,000**	**170,000**

6 The total will not add due to rounding errors.

Appendix D : Data Quality

D-1 Mixed C&D Waste Audit

The two types of error that can occur in a sample survey such as the Mixed C&D Waste Audit are sampling error and non-sampling error. The Australian Bureau of Statistics defines these errors as;

Sampling error: is the difference between the estimate derived from the survey and the 'true value' that would be obtained if the whole target population were included.

Non-sampling error: are errors caused by the process or operations of the survey and can be grouped into two main types. These are systematic and random errors.

Systematic errors (called bias) make the survey results unrepresentative of the target population by distorting the survey estimates in one direction. For example, if the auditors consistently incorrectly classified ferrous metals as non ferrous metals.

Random error can distort the results but tend to balance out on average. An example, is a concrete brick classified as a clay brick will more than likely balance out with a clay brick classified as a concrete brick.

D-2 Sampling Error

To minimise sampling error the Mixed C&D Waste Audit undertook a multistage sampling methodology using a combination of stratified and cluster sampling techniques.

The sample was stratified by landfill size (based on the quantity of mixed C&D waste disposed) and source flow (the vehicle type transporting this waste to landfill). This analysis identified 11 stratums for sampling.

Cluster sampling involved unloading truckloads of mixed C&D within each stratum into 100m^3 stockpiles, which were then mixed. From each 100m^3 stockpile a ~10m^3 sample was randomly selected for measurement.

The measurement process further stratified the sample into particle size fractions, with all material in each of the large-size fraction (>300mm) and medium-size fraction (30-300mm) measured and a sample of the small-size fraction (4.75-30mm) selected for laboratory analysis. The fine-size fraction (<4.75mm) was weighed and classified as a distinct component without compositional analysis.

Mixed C&D waste is comprised of heterogeneous materials with potential large variation in size. To understand the standard error of the sample selection process, analysis was undertaken on 5 samples from a single 100m^3 stockpile.

Although we are attempting to measure sampling error caused by sample selection there is potential non sampling error affecting the results depending on how thoroughly the 100m^3 stockpile was mixed before sample selection. An example, is the material type plasterboard in the large-size fraction which comprised only 11% of sample 3 but 56% of sample 2. This is more than likely the result of large sheets of plasterboard not thoroughly mixed through the stockpile.

Charts 29 to 31 show the average composition of each size fraction within the 5 stockpiles measured with the standard error measured at 90% confidence. As an example, for timber in the large-size fraction there is a 90% probability that the true compositional value is within the interval 30% to 50%.

Due to the heterogeneous composition and variance in particle size of mixed C&D waste, the standard error in composition was not unexpected.

Chart 29: Sampling Error of Stockpile Sample Selection Large-size fraction (90% Confidence Interval)

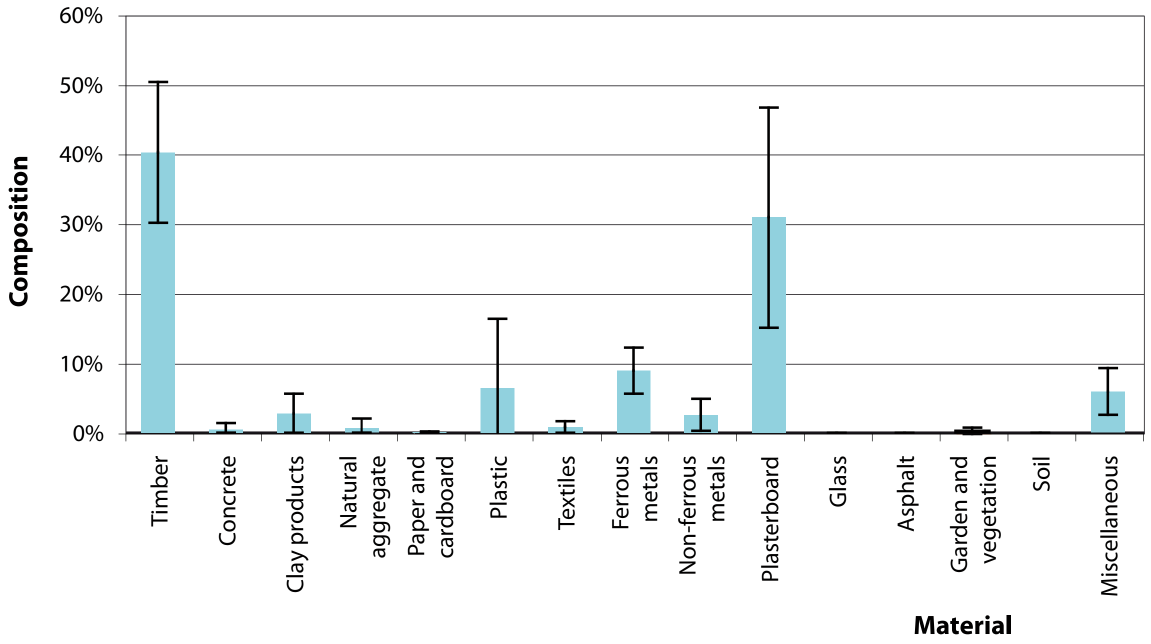


Chart 30: Sampling Error of Stockpile Sample Selection Medium-size fraction (90% Confidence Interval)

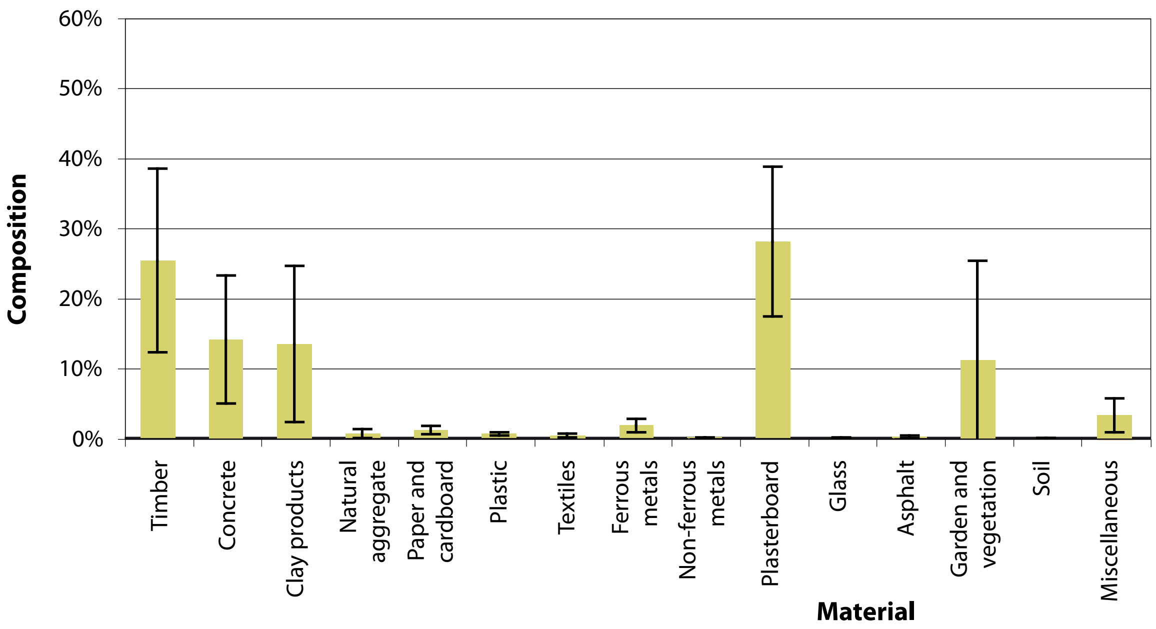
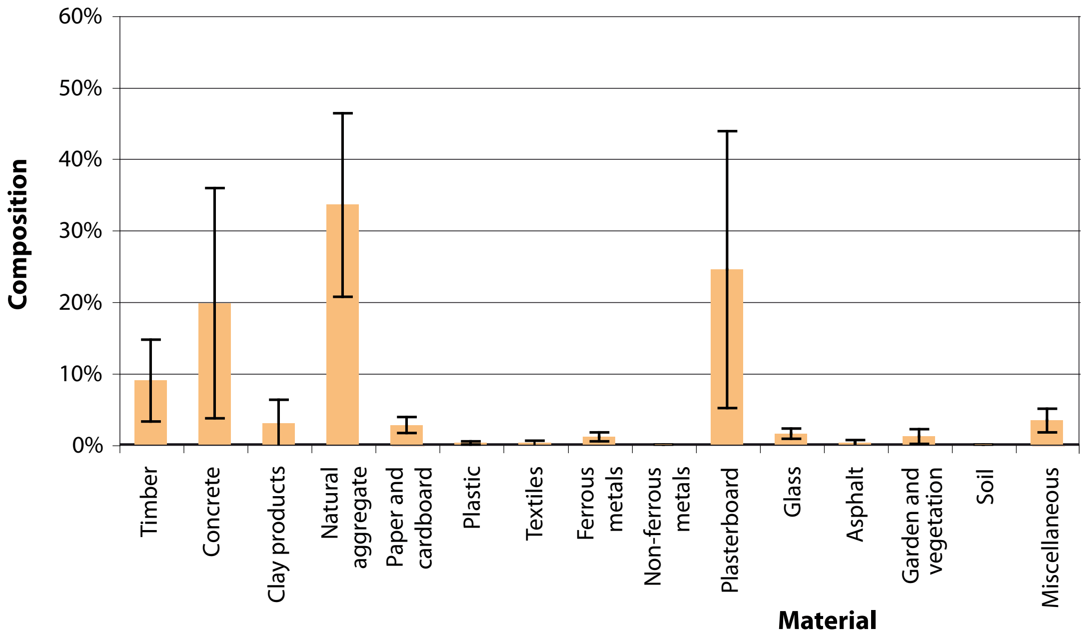


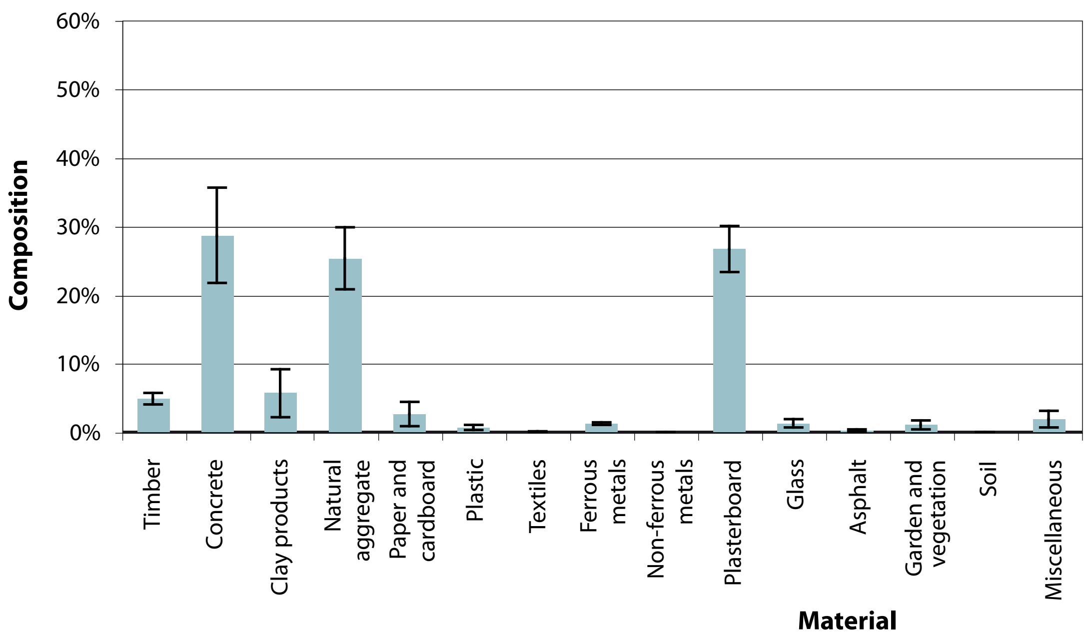
Chart 31: Sampling Error of Stockpile Sample Selection Small-size fraction (90% Confidence Interval)



The small-size particle fraction for each sample was weighed then further sampled for laboratory analysis. The sampling methodology required 2 x 20 litre buckets to be provided to the laboratory. For one sample, 10 x 20 litre buckets were submitted.

The standard error for the sampling of the small-size fraction at 90% confidence by material type is provided below in Chart 32. The results suggest, as expected, that this fraction within a stockpile sample is relatively homogenous.

Chart 32: Sampling Variance of Stockpile Sample Selection Small-size fraction (90% Confidence Interval)



D-3 Non-Sampling Error

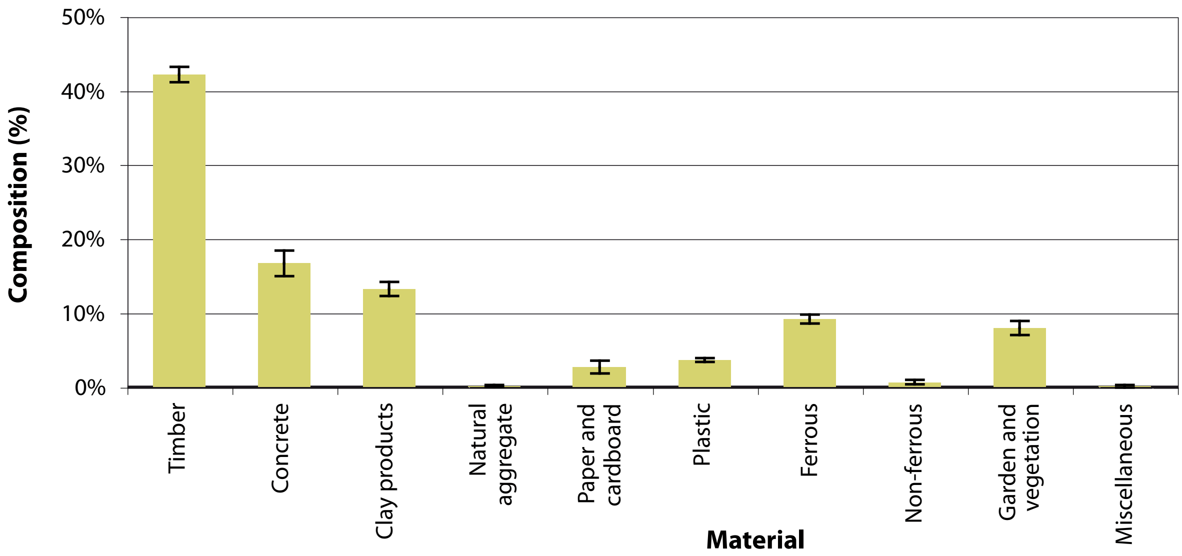
Non-sampling error can occur at every stage of the survey process. For the Mixed C&D Waste Audit, the physical sort and classification of materials was a stage in which non-sampling error could influence the results. As part of the quality assurance procedures and to understand the magnitude of possible non-sampling error at this stage of the audit, a stockpile sample of the medium-size particle fraction was sorted then mixed and re-sorted four times.

The object of the re-sorting process was to undertake a quality check on the ability of the auditors to consistently identify and correctly classify each material. The results are presented in chart 33 below.

The chart indicates that concrete and timber appear to be the most difficult material types to consistently classify, however, further investigation revealed that the quantity of concrete and timber after each successive re-sort was decreasing because the mixing process of trommelling the materials after each re-sort was causing physical breakdown, allowing them to pass through the 30mm screen into the small-size fraction.

After taking into consideration the physical breakdown of material through trommelling, the material classification ability of the auditors was of a high order. Therefore, there is no evidence to suggest that the results have been affected by non-sampling error associated with the material sorting and classification stage.

Chart 33: Non Sampling Error of Stockpile Re-sort Medium-size fraction



The physical sort and material classification of the audit required two sorting teams. Although, the methodology was prescriptive there is the risk that results have been affected by the interpretation of the methodology by each sorting team. During the audit both teams sorted samples from stockpiles within the same stratum.

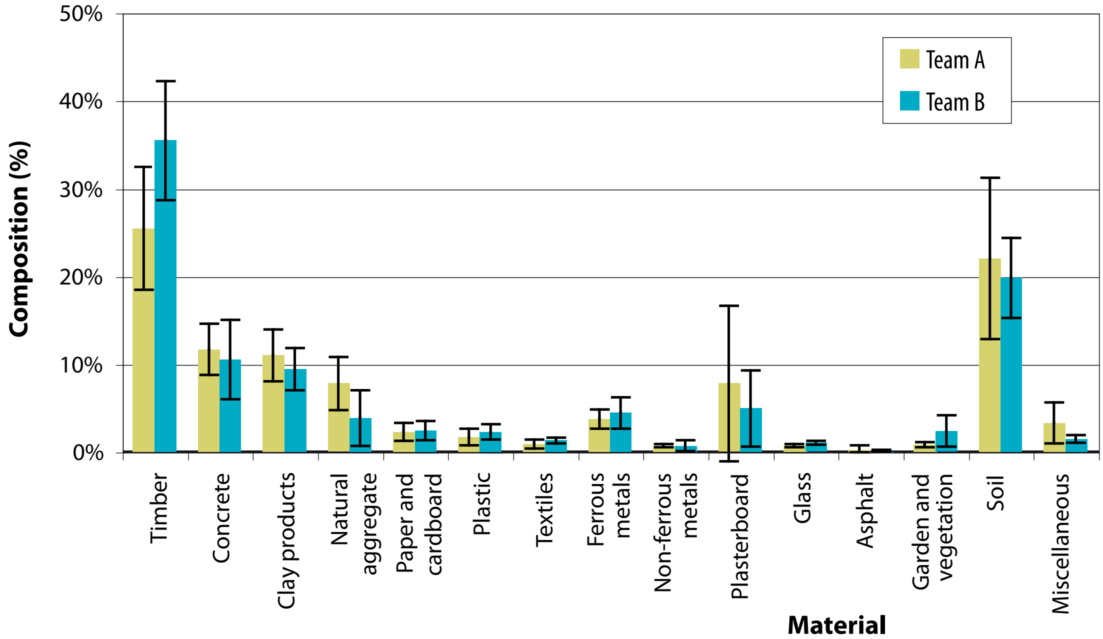
It is expected that the material composition of C&D waste within the same stratum should be similar. Therefore analysis was undertaken on the results achieved by each team when working on samples in the same stratum to assess whether there were significant variations between the teams.

Of the 15 material types measured, at 90% confidence, the result is a statistically non significant difference between sort teams A and B. The meaningful result is that the variability in the estimates makes the confidence intervals for each material so broad that the statistical result was not unexpected.

The small number of samples available for direct comparison between sort teams A and B contribute to the variability of results. In the first stratum, team A measured 4 samples compared to team B's 2 samples. In the third stratum, team A measured 2 samples compared to team B's 3 samples.

The results are presented in Chart 34.

Chart: 34 Variation of Results for Sort Teams A and B



D-4 Variation in Composition

Analysis was undertaken to measure the variation that could be expected at 90% confidence for the composition of mixed C&D waste. The results are presented in Charts 35 and 36.

Chart 35: Composition of Mixed C&D Waste as a percentage, 2004-05

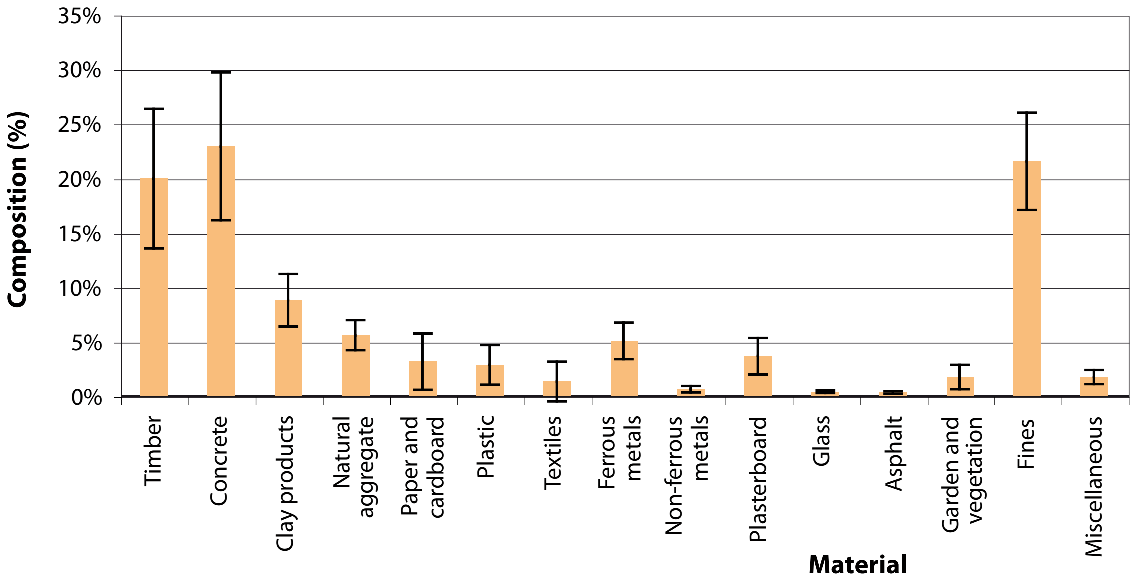
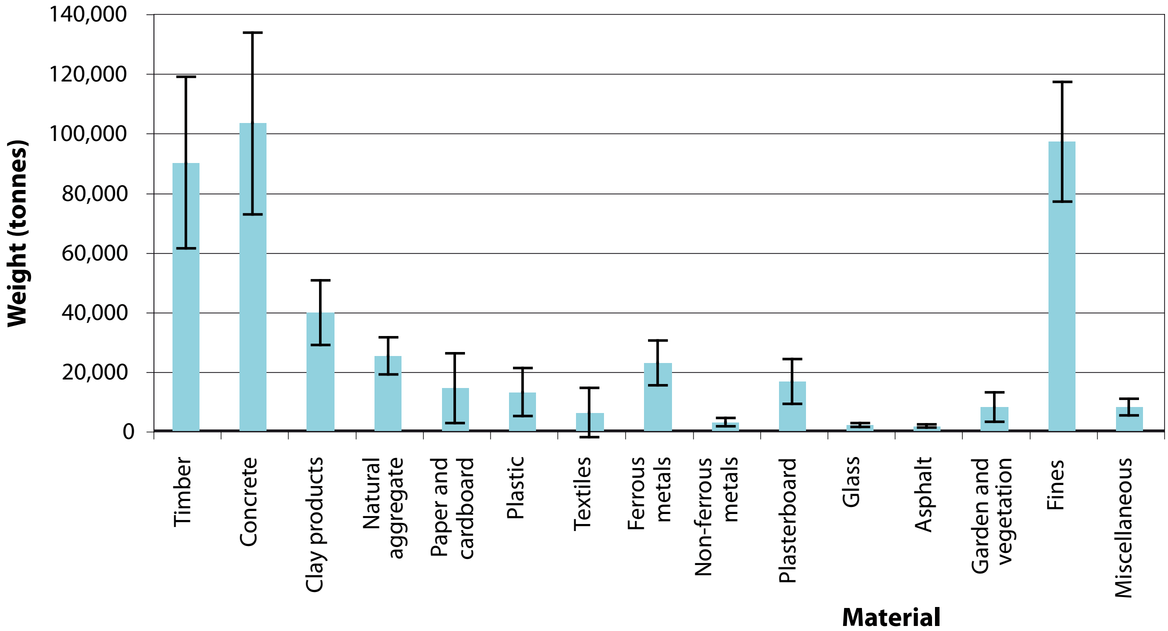


Chart 36: Composition of Mixed C&D Waste by weight, 2004-05



D-5 Waste Contribution Monthly Report Data

The Waste Contribution Monthly Report (WCMR) is required to be submitted to the Department of Environment and Climate Change NSW as part of the administration of the Waste Levy. The data determines the amount of contribution each licensed landfill in the Sydney Metropolitan Area is required to pay the NSW Government.

The WCMR includes recording the quantity of waste from C&D sources and whether this waste was recovered or disposed.

Data from the WCMR analysis therefore covers 100% of licensed waste facilities in the Sydney Metropolitan Area required to pay the Waste Levy and is therefore not subject to sampling errors associated with sample survey data.

The quality of this data is considered to be of a high standard because the data relates to the amount of levy to be paid and is subject to an audit process that carries potential penalties for incorrect reporting.

Appendix E : Material Classifications

Material Type	Material Detail	Material sub category
Paper		
Organic Compostable	Food/Kitchen	
	Garden	Vegetation
		Branches
		Logs
Other Organic	Timber	Hardwood
		Softwood
		Particleboard
		MDF
		Other engineered timber
	Textiles	Carpet
		Underfelt
		Other
	Leather	
	Rubber	
Glass		
Plastic	PVC	Plumbing
		Electrical conduits
		Cladding
	Polystyrene	
	Other	Builders film
		Polyurethane
		Other plastic
	Fibreglass	
Ferrous	Steel	
	Iron	
Non Ferrous	Aluminium	
	Copper	
	Stainless steel	
Earth based	Ceramic	
	Soil	
	Natural aggregates	Sandstone
		Basalt
		River pebbles
		Shale / clay
	Ash	
	Concrete	Rubble
		Tiles
		Bricks
		Pavers
		Aerated
	Clay	Tiles
		Bricks
		Pavers
	Plaster	Plasterboard
		Other (specify)
	Asphalt / bitumen	
	Fibrous sheeting	excluding asbestos sheeting
Unclassified		