ONC(SC)01/03

ONE NUMBER CENSUS STEERING COMMITTEE

Census Coverage Survey sample size, Coverage and the impact of dependence on the One Number Census

1. The research within this paper is a result of the outcomes from the Steering Committee meeting held on 28th June 2000.

2. The paper considers whether the coverage gains that might be made if the sample size were reduced would provide sufficient protection against high levels of dependence, and compares this against the price that will be paid in decreased precision due to a smaller sample size.

3. A simulation study has been undertaken to quantify the gains and losses in precision under different dependence and sample size scenarios. Both the simulation study and practical issues suggest that there is great risk in reducing the sample size of the CCS below 20,000 postcodes.

The Steering Committee are asked to note the paper.

Owen Abbott
Census Division
Office for National Statistics
Room 4200W
Segensworth Road
Titchfield
Fareham
HANTS
PO15 5RR

January 2001

Census Coverage Survey sample size, Coverage and the impact of dependence on the One Number Census

Owen Abbott, Marie Cruddas, Ian Diamond and John Dixie

EXECUTIVE SUMMARY

1. The research within this paper is a result of the outcomes from the Steering Committee meeting held on 28th June 2000. There are concerns that if there is a high level of dependence between the Census and the CCS then the current strategy is not robust enough to provide acceptable estimates under these circumstances.

2. The classical way of combating high levels of dependence when using Dual System Estimation is to ensure that both counting processes are near perfect. Achieving a perfect Census is beyond the scope of this paper, and so the focus is placed upon achieving high coverage levels in the Census Coverage Survey.

3. The current CCS strategy (see **Annex A**) is based upon a sample size of 20,000 postcodes. Test results have resulted in CCS coverages of around 85%, although it is expected that improvements can be made for 2001. However, the resources available to the CCS are fixed and hence if improvements in coverage are required then the sample size would have to be reconsidered.

4. The purpose of this paper is to consider whether the coverage gains that might be made if the sample size were reduced would provide sufficient protection against high levels of dependence, and compare this against the price that will be paid in decreased precision due to a smaller sample size.

5. A simulation study has been undertaken to quantify the gains and losses in precision under different dependence and sample size scenarios. The study included an assessment of the impact of these factors on the population estimates for the Local Authority Districts, which are the key ONC outputs.

6. The results show that as expected, extra protection is acquired against extreme levels of dependence for a 10,000 postcode, high coverage CCS. However, the price paid in precision of the population estimates for this sample size is considerable when compared against the current CCS sample size and expected coverage, especially if the Census and CCS are almost independent for the majority of the country.

7. The paper includes a discussion on whether the assumed increases in coverage through a reduction in sample size are attainable, and highlights the risks inherent in implementing a change of strategy within the timeframe.

8. Both the simulation study and practical issues suggest that there is great risk in reducing the sample size of the CCS below 20,000 postcodes. It is therefore recommended that the size of the CCS should be 20,000 postcodes.

Owen Abbott
Census Division, Room 4200W
Office for National Statistics
Segensworth Road
Titchfield
Fareham
Hampshire
PO15 5RR
Tel: 01329 813599
Fax: 01329 813407
Email: owen.abbott@ons.gov.uk

Census Coverage Survey sample size, Coverage and the impact of dependence on the One Number Census

Owen Abbott, Marie Cruddas, Ian Diamond and John Dixie

1. INTRODUCTION

1.1 The research within this paper is a result of the outcomes from the Steering Committee meeting held on 28th June 2000.

1.2 Previous research has determined that, given certain assumptions, the size of the CCS should be 20,000 postcodes (ONC(SC)98/12). This would provide population estimates of an acceptable precision. The particular set of assumptions that led to this result included the independence of the Census and CCS. Further research (ONC(SC)00/16) investigated the impact on the precision of relaxing this assumption. The conclusion was that the impact decreases as the coverage of both Census and CCS increases.

1.3 It is likely that in 2001, the Census and CCS will not be perfectly independent. However, the degree of dependence is difficult to estimate beforehand. There is no relevant evidence from previous censuses and surveys either in the UK or internationally to give an indication. Therefore it is sensible to evaluate the options for minimising the risk that the ONC estimates are unacceptable due to unpredictable dependencies between the Census and CCS.

1.4 The most sure-fire method for achieving this would be to ensure the CCS achieves the highest possible coverage beyond the already achieved high levels. The design, testing and implementation plans for the CCS are described in **Annex A**. Previous CCS tests have resulted in estimated coverages of approximately 85%. Further increases might only be possible through a large amount of additional resource. However, within the constraints of the CCS budget this could only be realistically achieved by a reduction in the sample size.

1.5 Therefore it is proposed to evaluate the impact of reducing the CCS sample size but assuming the extra resource results in increased CCS coverage. The paper is split into two main sections – Precision of estimates and Practical issues. The first presents the results of a simulation study that provides information about the properties of the estimates under different sample size, coverage and dependence assumptions. The second considers the practical implications and issues for attaining higher levels of coverage through a redistribution of resources.

2. PRECISION OF ESTIMATES

2.1 Introduction

2.1.1 Three national sample sizes will be examined – 20,000 Postcodes (which is the current proposed sample size), 15,000 Postcodes and 10,000 Postcodes. For each of these an assumption will be made on the likely increases in CCS coverage that could be made through a reduction in sample size. These three options will be implemented within a simulation study to enable an examination of the properties of the resulting estimates.

2.1.2 The impact of dependence for each of the CCS sample size scenarios will also be evaluated. This will ensure that key comparisons can be drawn from different levels of assumed dependence.

2.2 Methodology

2.2.1 In order to evaluate the precision of the estimates for the different scenarios described above, each was implemented within a set of simulations in order to compare their relative performance. The simulations were carried out on the same basis as those used for previous One Number Census research (see Brown *et al* (1999)), albeit on a slightly more extended basis as described below.

Simulation Data

2.2.2 A Design Group consisting of Southampton, Eastleigh and Test Valley Districts was chosen for this research. The reason for this was mainly that it represented an area where there may be a good degree of variability in the underenumeration and therefore should provide more information on the impact of altering the CCS strategy.

2.2.3 The coverage in the Census was set at an overall level of 95%. As in previous research, coverage varied by agegroup, the Hard to Count index and other household level and individual level factors. The Census coverage levels for each Local Authority and the overall Design Group by agegroup are shown in **Annex B**.

2.2.4 The CCS design for the selection of PSUs (these are 1991 Enumeration Districts) was fixed throughout each CCS sample size simulation, and 5 postcodes per ED were randomly taken at the second stage. It must be noted that the design strategy detailed in ONC(SC)00/11 would not be used for a CCS of size 10,000 postcodes – a complete redesign of the CCS would be required but this is out of the scope of this research.

2.2.5 For each sample size scenario, coverage levels in the CCS were varied – as described in the introduction, gains in coverage might be made if the sample size was smaller. **Table 1** shows the coverages used for each of the CCS sample sizes.

Table 1: Overall Design Group Census Coverage Survey simulation coverage levels.

CCS sample size	Primary Sampling Units	CCS coverage of Households	CCS coverage of Person within household	CCS coverage of Overall
20,000 Postcodes	40	90%	97%	88%
15,000 Postcodes	30	94%	98%	92%
10,000 Postcodes	20	98%	99%	97%

2.2.6 Each of the sample sizes and associated CCS coverages in **Table 1** were simulated. These produced population estimates at both Design Group and Local Authority District level using the methodologies outlined in papers ONC(SC)00/03A, ONC(SC)00/03B and ONC(SC)00/16.

Dependence

2.2.7 Each sample size was simulated four times – each using a different assumed level of dependence between the Census and CCS. The levels of dependence used were odds ratios of 1 (independence), 2, 8 and 1/8. These were chosen to provide information about the more extreme levels of dependence.

2.2.8 An odds ratio greater than 1 represents the situation where people counted in the census are more likely to be counted by the CCS, and therefore the CCS find less of the missed people – and the DSE underestimates the population. An odds ratio of less than 1 is the situation where people missed in the census are more likely to be counted by the CCS, and so the CCS is good at finding the missed people – and hence the DSE overestimates the population. Intuitively, the 2001 odds ratio is likely to be greater than 1.

2.2.9 The simulations assume the same level of dependence everywhere – this is not likely to be particularly realistic as we would expect it to vary across area and population types. Therefore the results presented below show the worst case scenario – the impact of the bias on the estimator would be lessened if the extreme levels of dependence were to occur in just a few PSUs within a particular Hard to Count category.

2.3 Results

2.3.1 The key measures of performance are the Relative Root Mean Squared Error (RRMSE), Relative Standard Error (RSE) and Relative Bias of the population estimates. These actual error and bias values can be calculated since the true value of the populations are known. The great benefit of using the RRMSE measure in particular is that it contains both a variance and bias component – and therefore our evaluation can take both into account. The mean of the errors across all 1000 simulations are used in the analysis. A description of the RRMSE, RSE and Bias calculations can be found in **Annex C**.

2.3.2 Following the presentation of these results to the ONC Project Board, further work has been carried out to include the case where the CCS coverage is lower than expected. These simulations are reported in **Annex D**.

Design Group results

2.3.3 **Table 2** below displays the Relative RMSE of the Design Group total population estimates for each of the simulation runs. It shows that for odds ratios of 1 and 2, the CCS of size 20,000 has a superior level of precision. However, when extreme levels of dependence are simulated, the error levels increase most dramatically where the CCS coverage is lowest – and the increase is greatest for the odds ratio of 8. This is mainly driven by the increased bias in the estimates due to the dependence. For this extreme dependence scenario, the error level associated with the 10,000 postcode CCS is the best.

Table 2: Relative Root Mean Square Error (%) for Design Group total population estimate to 2 d.p.

		Odds Ratio			
CCS sample size (Postcodes)	**CCS coverage**	**1/8**	**1**	**2**	**8**
10,000	**97%**	**0.73%**	**0.72%**	**0.73%**	**0.80%**
15,000	**92%**	**0.64%**	**0.58%**	**0.58%**	**0.89%**
20,000	**88%**	**0.66%**	**0.50%**	**0.50%**	**1.13%**

2.3.4 It is also useful to examine the Relative Standard Error (RSE), which is the square root of the prediction variance expressed as a percentage. **Table 3** shows that as the odds ratio changes, the RSE is stable and displays a slight downward trend. The downward trend is due to the constraining of the estimation to be at least as big as the census counts – and hence under an odds ratio of 8 where the CCS is very nearly a repeat of the census the variance of the estimator will decrease, albeit by a small amount. The stability of the RSE is in contrast to the rapid changes in the RRMSE, which includes a bias component. However, it does indicate that the variance associated with the estimator will be reasonably consistent regardless of the odds ratio.

Table 3: Relative Standard Error (%) for Design Group total population estimate to 2 d.p.

		Odds Ratio			
CCS sample size (Postcodes)	**CCS coverage**	**1/8**	**1**	**2**	**8**
10,000	**97%**	**0.73%**	**0.72%**	**0.71%**	**0.69%**
15,000	**92%**	**0.60%**	**0.58%**	**0.56%**	**0.52%**
20,000	**88%**	**0.52%**	**0.49%**	**0.46%**	**0.41%**

2.3.5 The impact of dependence on the bias of the estimator is particularly important. Previous dependence research (see ONC(SC)00/16) concluded that odds ratios greater than 1 induced a negative bias into the estimates, and those less than one induced a positive bias. However, the impact of any level of dependence decreases as the Census and CCS coverages increase. This pattern is repeated in **Table 4** below, which shows the changes in Relative Bias associated with the population estimates from independence (for which the estimator is approximately unbiased). To put these figures in some sort of context, the relative bias in the Census for these simulations was -5.11%.

Table 4: Change in Relative Bias (%) from odds ratio 1 for Design Group total population estimate to 2 d.p.

CCS sample size (Postcodes)	CCS coverage	Odds Ratio 1/8	1 Base	2	8
10,000	**97%**	**0.07%**	**0**	**-0.07%**	**-0.32%**
15,000	**92%**	**0.19%**	**0**	**-0.17%**	**-0.78%**
20,000	**88%**	**0.32%**	**0**	**-0.27%**	**-1.16%**

2.3.6 **Table 4** demonstrates the change in bias due to the odds ratio. It shows that for a high CCS coverage, the impact of changing the odds ratio on the bias is less than for lower CCS coverages. In the case of an odds ratio of 8, increasing the CCS coverage from 88% to 97% with the associated drop in sample size reduces the change in bias by roughly three quarters.

Local Authority District Results

2.3.7 It is also important to examine the properties of the Local Authority District estimates, since these will be the published populations that will be scrutinised thoroughly by Census users, including the Authorities themselves. Furthermore, the LAD estimation procedure is likely to be more sensitive to changes in sample size than the Design Group estimates and the smaller CCS sample sizes may result in unfeasible error levels.

2.3.8 **Tables 5 and 6** show the Relative RMSEs and Biases obtained for the total LAD population estimates. Care must be taken when interpreting the figures, since the LAD estimates have been calibrated to sum to the Design Group estimates. Therefore a negatively biased Design Group estimate will by its nature generate negatively biased LAD estimates.

Table 5: Relative RMSE (%) for LAD total population estimates to 2 d.p.

CCS sample size (Postcodes)	CCS coverage	LAD	Odds Ratio 1/8	1	2	8
10,000	**97%**	**JF**	**0.88%**	**0.90%**	**0.90%**	**0.93%**
		JP	**1.27%**	**1.25%**	**1.26%**	**1.29%**
		JQ	**1.06%**	**1.17%**	**1.16%**	**1.15%**
15,000	**92%**	**JF**	**0.81%**	**0.80%**	**0.81%**	**1.02%**
		JP	**1.14%**	**1.04%**	**1.01%**	**1.21%**
		JQ	**1.02%**	**0.98%**	**0.96%**	**1.05%**
20,000	**88%**	**JF**	**0.73%**	**0.70%**	**0.74%**	**1.18%**
		JP	**1.09%**	**0.88%**	**0.84%**	**1.38%**
		JQ	**0.99%**	**0.88%**	**0.82%**	**1.10%**

2.3.9 **Table 5** shows that, for odds ratios of 1 and 2, the 20,000 postcode CCS provides the best precision levels for the LAD estimates. However, for extreme odds ratios the 15,000 Postcode CCS and 10,000 Postcode CCS have the better precision. Again, in the extreme dependence scenarios the bias predominately drives the RRMSE for the largest CCS. However, the differences between the sample sizes in terms of this measure is not as large as for the Design Group. This due to the LAD estimates becoming more unstable due to the much smaller sample sizes within each LAD.

Table 6: Relative Bias (%) for LAD total population estimates to 2 d.p.

			Odds Ratio			
CCS sample size (Postcodes)	**CCS coverage**	**LAD**	**1/8**	**1**	**2**	**8**
10,000	**97%**	**JF**	**-0.10%**	**-0.15%**	**-0.20%**	**-0.41%**
		JP	**-0.03%**	**-0.12%**	**-0.20%**	**-0.49%**
		JQ	**0.06%**	**>-0.01%**	**-0.06%**	**-0.28%**
15,000	**92%**	**JF**	**>-0.01%**	**-0.14%**	**-0.27%**	**-0.78%**
		JP	**0.37%**	**0.12%**	**-0.08%**	**-0.78%**
		JQ	**0.24%**	**0.09%**	**-0.05%**	**-0.59%**
20,000	**88%**	**JF**	**0.11%**	**-0.11%**	**-0.33%**	**-1.04%**
		JP	**0.57%**	**0.17%**	**-0.15%**	**-1.17%**
		JQ	**0.42%**	**0.16%**	**-0.05%**	**-0.84%**

2.4 Discussion

2.4.1 It is important to consider what these error and bias results mean in terms of the actual outcome of the estimation.

2.4.2 Consider the case where a high level of dependence is experienced across all areas and agesex groups of a Design Group. The simulation results show, if the coverage levels simulated are achieved, that a CCS of size 20,000 postcodes will underestimate the population by roughly 1.2% (an estimate of 494,000 where the true population is 500,000). For a CCS of size 15,000 postcodes the Design Groups estimate will be 496,000 (underestimated by 0.8%) and for 10,000 postcodes it will be 498,000 (underestimated by 0.4%).

2.4.3 However, because of the size of the largest CCS, the variance associated with the Design Group estimate is low – the 95% confidence interval around the estimate will be roughly ±4100 (note that this does not include the true population). However, for the smaller CCS sizes this interval will be larger - ±5000 persons for the 15,000 postcode CCS and ±6700 persons for the 10,000 postcode CCS.

2.4.4 A similar result applies to the Local Authority population estimates. These will also be underestimated - for instance by 1% for a 20,000 postcode CCS (for a Local Authority size 150,000 the estimate will be 148,500). Again, the larger CCS will provide more sample and hence the variance associated with these will be smaller.

2.4.5 While the above shows that the Design Groups estimates will be worst for a large CCS with poorer coverage, the estimates obtained under this scenario are still much better than the Census itself. Because the 95% confidence interval is narrow due to the larger sample size, the estimates are likely to be treated with suspicion within the ONC QA strategy, which is designed to investigate where the estimates are unreliable. Even so, the target of 1% accuracy at Design Group level (see **Annex A**) is almost met.

2.4.6 These results are all based upon the key assumption that a high level of dependence is experienced across the whole design group both geographically and demographically. This is possible in perhaps a single Design Group if there was a major failure to ensure operational independence. For example, if Census enumerators were employed in the CCS in the same areas or, a systematic problem with the address data used by the Census to generate the initial household listing and the CCS to generate postcode maps.

2.4.7 However, due to the operational procedures being adopted in the CCS this is not likely to be the case for the rest of the country. In these areas it is the smaller CCS samples that will provide less accurate estimates. For instance, under near independence the errors associated with the Design Group estimates will be largest for the 10,000 postcode CCS. The best CCS sample size in these cases is 20,000 postcodes, especially for the estimation of the Local Authority populations.

2.4.8 Therefore there is a significant premium in terms of overall error to be paid for the extra protection gained from a smaller but higher coverage CCS. Regardless of the levels of dependence, a high coverage 10,000 postcode CCS would struggle to meet the target accuracy levels for Local Authority population estimates. Although the 15,000 postcode CCS might meet these requirements, it does not provide big gains in protection against high levels of dependence as the 10,000 postcode CCS.

2.4.9 The current CCS strategy is aimed at obtaining a high coverage, independent CCS and the research and testing to date has suggested that this will be mainly achieved. All of these indications suggest that the extra protection from dependence might not be necessary if extreme levels of dependence are experienced in extremely rare cases.

2.5 Conclusions

2.5.1 The simulations have shown that while a smaller, high coverage CCS provides good protection against high levels of dependence, it is a less efficient use of resources in terms of precision when the CCS is reasonably independent. The current CCS sample size and expected coverages provide estimates with superior precision under these circumstances.

2.5.2 Since it is likely that the majority of the CCS will be near independence due to the operational procedures in place to avoid dependence (see **Annex A**), the largest CCS is the best option. It can therefore be concluded that the reduction in the precision of the estimates derived from a smaller CCS outweighs the protection against extreme dependence.

3 Practical Issues

3.1 Introduction

3.1.1 This section explores some of the practical issues associated with attaining higher levels of coverage and reducing the sample size. The following are discussed:

- CCS Design
- Coverage
- Implementation

3.2 CCS Design

3.2.1 The CCS Design strategy has been developed based upon a national sample size of 20,000 postcodes. If this national sample size were to change, it would be necessary to consider whether the strategy should be altered. In the case of sampling 10,000 postcodes the strategy would certainly have to revisited. This represents a risk to the successful implementation of the CCS, since the sample of postcodes using the current approach has to be drawn by mid October 2000 at the latest to allow the final calculation of the number of required fieldstaff for recruitment.

3.3 Coverage

3.3.1 Broadly a reduction in the size of the CCS sample but keeping the budget the same can be translated into:

a) the same number of interviewers each with a reduced workload and a more intensive survey; or;
b) fewer CCS interviewers required with the same size workload.

3.3.2 If we consider situation a), the methodology for conducting the CCS has been developed with the aim of giving the Interviewers the best training, suitable workloads, effective calling strategies and enough time in which to maximise the coverage in their postcodes. So it is arguable whether a reduction in workload can have much impact on coverage.

3.3.3 For situation b), on the other hand, if fewer interviewers are required then their overall quality should improve and this could be translated into improved coverage.

3.3.4 In either situation is difficult to quantify any improved coverage. However it is perhaps worth noting that the 1999 CCS Rehearsal in Northern Ireland was conducted by NISRA's equivalent of Social Survey Division (SSD) in ONS, the Central Survey Unit (CSU). Using a broadly similar methodology to the CCS Rehearsal in England and Wales, they achieved a coverage rate of 87.2% - this was within the range of 79.8% - 96.3% achieved elsewhere.

3.3.5 For the 2001 CCS, changes to the monitoring and management scheme used in the 1999 Rehearsal will be introduced, designed to raise coverage in the harder areas within the same general size of workload that has been used in earlier testing. Also, the evaluation of the calling patterns observed in 1999 is being used to feed into the development of optimal calling strategies for 2001.

3.3.6 It is not possible to estimate with any confidence what percentage additional coverage increased interviewer resources would achieve, given the improvements above. The CCS Project is dubious that the highest coverage levels used in the simulation – 98% of households and 99% of individuals within surveyed households – could be achieved no matter how much resource was deployed.

3.3.7 However, an overall coverage level of 94% of households, 98% persons in counted households is a more attainable realistic maximum. However, further testing would have to be undertaken to prove that this level could actually be achieved in practice.

3.5 Implementation

3.5.1 Plans for the management structure would not be affected by reducing the sample size since the size of the interviewer force would be the same. Slightly fewer public forms would be required to be printed. Fewer forms would be required to be processed according to the option chosen. Some cost savings in these instances might be achieved.

3.6 Conclusions

3.6.1 The practical issues discussed above suggest that while a smaller CCS could be implemented, further work would have to be carried out, particularly to examine whether gains in coverage can be achieved. This presents a risk to the plans that are currently in place, and suitable additional resource would be required immediately to absorb this extra work and assess the impacts on the overall CCS plans and processes.

4 Recommendation

4.1 Both the simulation study and practical issues suggest that there is great risk in reducing the sample size of the CCS below 20,000 postcodes. Firstly, there will be a significant loss in precision in areas where dependence is not extreme. For the majority of the country this is likely to be the case.

4.2 Secondly, there is some doubt that a reduction in sample size would increase the levels of coverage significantly beyond the levels already demonstrated in the CCS testing programme, and there will be other associated issues if the sample size were altered.

4.3 It is therefore recommended that the size of the CCS should be 20,000 postcodes.

References:

Brown, J. J., Diamond, I. D., Chambers, R. L., Buckner, L. J., and Teague, A. D. (1999)[1] A methodological strategy for a One Number Census. *Journal of the Royal Statistical Society A* **162**, 247-267.

ONS(ONC(SC))98/12 – Census Coverage Survey: The precision of population estimates for different sample sizes and design areas.

ONS(ONC(SC))00/03A – Estimation strategy for Design Group Estimates by age and sex from the Census Coverage Survey.

ONS(ONC(SC))00/03B – One Number Census Local Authority Estimation.

ONS(ONC(SC))00/11 – 2001 One Number Census Methodology

ONS(ONC(SC))00/16 – One Number Census Estimation Update

ANNEX A - BACKGROUND INFORMATION ON THE CENSUS COVERAGE SURVEY IN ENGLAND AND WALES

A1 Design and Sample Size

A1.1 The primary aim of the One Number Census project is to provide undercount adjusted census estimates of population by age and sex at the Local Authority District Level to serve as a new base for the mid-year population estimates. However to design the CCS to give a specific accuracy at the LAD level the sample size would be prohibitively large. Thus the LADs have been grouped together in to 'Design Groups' of about half a million population and the CCS design has been applied at this level

A1.2 The work carried out to determine the optimal sample size for the CCS in terms of accuracy and practical implementation is described in ONS(ONC(SC))98/12. The work showed that a sample size of 20,000 postcodes (approximately 300,000 households) gives a relative error of less than 1% at the Design Group level and 0.1% at the national level. Of course the important estimates are those for LADs and simulation studies were undertaken to determine the accuracy at this level. For this work census coverage of 95% was assumed, with CCS coverage of households of 90% and of individuals within households of 98%.

A1.3 A Design Group was constructed from 1991 Census individual records for four LADs with populations of 190,000, 181,700, 30,800 and 123,700. For this work the estimation at the LAD level used a simple apportionment method - further work into the LAD level estimation has recommended a more robust approach.

A1.4 The table below shows the levels of accuracy observed in the simulated population estimates. For the Design Group as a whole, all except one of the 1,000 simulated population estimates were within 2% of the true underlying population. It should be noted that this design group is broadly representative of the demographic and social characteristics of the country as a whole.

Table A1: Percentage of simulated population estimates within 0.5%, 1%, 2% and 5% of the true population.

		Percentage of estimates within ±x% of the true population			
	True Population	**±0.5%**	**±1%**	**±2%**	**±5%**
Design Group	526,200	59%	89%	100%	100%
LAD1	190,000	42%	74%	98%	100%
LAD2	181,700	46%	79%	99%	100%
LAD3	30,800	56%	84%	100%	100%
LAD4	123,700	55%	86%	100%	100%

A2 Developing the practical aspects of the CCS

A2.1 In developing the methodology for conducting the CCS a number of tests have been carried out. The major tests are described below.

A2.2 **Brent Pilot:** 21st – 25th July 1997, following the Census Test on 15th June. Using 4 interviewers covering 20 postcodes in Brent this small pilot established the feasibility of conducting a postcode based survey and offered areas for further work. The four interviewers worked in pairs for the Monday to Friday period and achieved a 59% contact rate with a 43% response rate.

A2.3 **Test CCS:** 29th September - 21st October 1998. This study built on the practical issues highlighted by the Brent Pilot, including:

- production of postcode maps in large numbers
- methods to indicate where not to enumerate
- using members of the public as interviewers
- recruiting members of the public to manage the fieldwork locally
- developing interviewer training requirements and techniques
- using pre-warning postcard to inform public of the survey
- investigating the optimum timing of fieldwork to maximise response.

For the Test 100 postcodes were selected covering the range of the Hard to Count Index, 24 interviewers and two team supervisors were recruited. The interviewers in total listed 2,086 households and achieved 89.3% interviews, with 4.6% refusals and 6.1% non-contacts.

A2.4 **Rehearsal CCS:** 20th May – 13th June 1999, following the Census Rehearsal on 25th April. This was carried out in all the Census Rehearsal areas in England and Wales, Scotland and Northern Ireland to evaluate all aspects of implementing the ONC – in particular the practical aspects of carrying the CCS. To provide a large sample in order to test the practical aspect of the CCS in the Rehearsal the CCS was larger in proportion to the Census Rehearsal than will be the case with the 2001 Census and there were also a disproportionally large number of areas with high Hard to Count values. In England and Wales 818 postcodes were selected and 16 Team Managers and 240 Interviewers recruited. The key areas of evaluation were:

- Field Staff Structure and Management
- Recruitment
- Pay and Expenses
- Training and Instructions
- Interviewer Workloads
- Calling Strategies
- Interviewer Questionnaire
- Field Procedures
- Logistics & Field Material

A2.5 Overall there was an 84.5% response rate, with 8.8% refusals and 6.7% non-contacts. The response rates ranged from 79.8% in Leeds to 96.3% in Angus. In Northern Ireland where the fieldwork was carried out by their equivalent of Social Survey Division the response rate was 87.2%.

A2.6 In practical implementation terms the Rehearsal CCS was a resounding success. It also provided important information about how to improve both coverage and quality for the 2001 CCS through the analysis of the data recorded on calling times, the introduction of an additional level of management in the field, improved management information systems and a community liaison programme.

A3 The Fieldwork Structure for 2001

A3.1 As briefly referred to above the Rehearsal CCS has led to some changes in the proposed fieldwork structure for the 2001 CCS. The three level structure comprises: 33 Field Managers; 270 Team Managers and 3,600 Interviewers. This integrates with the 101 CCS Design Groups so that rather than conducting a single very large survey of 20,000 postcodes we have 33 independently conducted surveys of roughly 600 Postcodes (approximately 9,000 households) each run by a Field Manager supported by 8 Team Managers, each managing a team of up to 20 Interviewers.

ANNEX B – SIMULATION CENSUS COVERAGES

***Table B1:** Mean Simulation Census Coverage (%) by 5 year age-sex group and Local Authority District*

	Local Authority District			
Agegroup	**Eastleigh**	**Southampton**	**Test Valley**	**Overall Design Group**
Males 0-4	95.9	94.8	96.3	95.4
5-9	96.0	95.3	96.0	95.7
10-14	96.5	96.0	96.3	96.2
15-19	96.3	94.6	94.7	95.1
20-24	95.6	83.6	90.9	87.8
25-29	94.9	87.6	93.5	90.8
30-34	95.5	93.6	95.1	94.5
35-39	95.9	94.8	95.2	95.2
40-44	96.1	95.3	95.8	95.6
45-49	95.9	95.7	96.2	95.9
50-54	96.2	95.5	95.8	95.8
55-59	95.9	95.0	96.0	95.5
60-64	95.8	95.4	96.0	95.7
65-69	95.5	95.3	95.9	95.5
70-74	95.9	95.3	95.5	95.5
75-79	95.5	95.1	95.3	95.2
80-84	94.5	95.3	93.9	94.8
85+	93.5	93.0	95.1	93.6
Females 0-4	96.2	94.8	96.0	95.4
5-9	96.1	95.7	96.4	96.0
10-14	96.7	96.0	96.5	96.3
15-19	96.4	95.2	96.4	95.8
20-24	96.1	90.9	95.5	93.1
25-29	95.9	93.3	96.0	94.6
30-34	96.1	95.3	96.7	95.9
35-39	96.2	96.0	96.8	96.3
40-44	96.5	95.8	96.4	96.1
45-49	96.1	95.8	96.4	96.1
50-54	95.9	95.5	96.3	95.8
55-59	95.6	95.4	96.0	95.6
60-64	95.6	95.3	95.7	95.5
65-69	95.5	95.0	95.6	95.2
70-74	95.2	95.0	95.2	95.1
75-79	94.7	94.3	95.0	94.6
80-84	93.5	94.5	94.4	94.3
85+	92.3	91.4	93.2	92.0

ANNEX C – Description of terms used

C1 Relative Root Mean Square Error

For a given population quantity such as the total T with estimator $\hat{T}$, one can measure the mean accuracy of the estimator using the relative root mean square error (RRMSE) defined as:

$$\text{Relative RMSE}(\hat{T}) = \frac{1}{T}\left\{\sqrt{\frac{\sum(\hat{T}-T)^2}{n}}\right\}.100$$

where the summation is carried out over all the *n* observations of $\hat{T}$.

The RRMSE is a measure of the mean level of variability for a population total, relative to the population total being estimated.

C2 Mean Square Error

For a given population quantity such as the total T with estimator $\hat{T}$, one can measure the mean accuracy of the estimator using the mean square error (MSE) defined as:

$$\text{MSE}(\hat{T}) = \frac{\sum(\hat{T}-T)^2}{n}$$

where the summation is carried out over all the *n* observations of $\hat{T}$.

The MSE is a measure of the mean level of variability for a population total. The MSE includes a measure of the bias for the population estimate.

C3 Relative Standard Error

For a given population quantity such as the total T with estimator $\hat{T}$, one can measure the relative prediction variance of the estimator using the relative standard error (RSE) defined as:

$$\text{Relative Standard Error}(\hat{T}) = \frac{1}{T}\left\{\text{var}(\hat{T}-T)^{1/2}\right\}100$$

C4 Relative Bias

T For a given population quantity such as the total T with estimator $\hat{T}$, one can measure the bias of the estimator, relative to the truth, using the Relative Bias defined as:

$$\text{Relative Bias}(\hat{T}) = \frac{1}{T}\left\{\frac{\sum(\hat{T}-T)}{n}\right\}.100$$

where the summation is carried out over all the *n* observations of $\hat{T}$.

ANNEX D – THE IMPACT OF LOWER CCS COVERAGE LEVELS

D1 Introduction

D1.1 The ONC Project Board asked for further work to examine less optimistic CCS coverage levels for the different sample sizes and dependence levels.

D1.2 Further simulations were run using overall CCS coverage levels of 80% for a 20,000 postcode CCS, 85% for a 15,000 postcode CCS and 90% for a 10,000 postcode CCS. However, not all dependence levels were simulated due to time constraints. As a compromise the 20,000 postcode CCS was simulated with an odds ratio of 8, the 15,000 postcode CCS was simulated with an odds ratio of 4 (as this is roughly halfway between 1 and 8) and the 10,000 postcode CCS with an odds ratio of 1. This is to provide the key comparisons necessary for the evaluation.

D2 Results

D2.1 **Table D1** below displays the Relative RMSE of the Design Group total population estimates for each of the simulation runs. When compared with the figures in **Table 2**, it can be seen that the reduction in CCS coverage has resulted in no change for the 10,000 postcode CCS. This is a because the Dual System Estimator is still performing well at this level of coverage under independence. However, the 20,000 postcode CCS with an odds ratio of 8 is performing worse as one would expect for a lower coverage CCS. The 8% drop in coverage has led to an increase of 34% in the overall error level. This reinforces the need for high coverage when there is extreme dependence between the two counting processes.

Table D1: Relative Root Mean Square Error (%) for Design Group total population estimate to 2 d.p.

			Odds ratio	
CCS sample size (Postcodes)	**CCS coverage**	**1**	**4**	**8**
10,000	**90%**	**0.73%**		
15,000	**85%**		**0.92%**	
20,000	**80%**			**1.52%**

D2.2 **Table D2** below, which shows the Relative Bias associated with the total population estimates. To put these figures in some sort of context, the relative bias in the Census for these simulations was -5.11%. The bias has become more pronounced for the largest CCS, increasing by 26%.

Table D2: Relative Bias (%) for Design Group total population estimate to 2 d.p.

			Odds ratio	
CCS sample size (Postcodes)	**CCS coverage**	**1 Base**	**4**	**8**
10,000	**90%**	**-0.05%**		
15,000	**85%**		**-0.76%**	
20,000	**80%**			**-1.46%**

D2.3 **Table D3** shows the Relative RMSEs obtained for the total LAD population estimates. It shows that, as expected, the lower coverage levels than previous simulation has resulted in increased error levels. The increases are greatest for the largest CCS due to the high level of dependence.

Table D3: Relative RMSE (%) for LAD total population estimates to 2 d.p.

			Odds ratio		
CCS sample size (Postcodes)	**CCS coverage**	**Local Authority District**	**1**	**4**	**8**
10,000	**90%**	**JF**	**0.92**		
		JP	**1.26**		
		JQ	**1.20**		
15,000	**85%**	**JF**		**1.04**	
		JP		**1.26**	
		JQ		**1.07**	
20,000	**80%**	**JF**			**1.43**
		JP			**1.82**
		JQ			**1.36**

D3 Conclusions

D3.1 These additional simulations demonstrate further the importance of attaining a high level of coverage in the CCS. Under independence, there is little difference in the DSE performance for CCS coverage levels of 90% or more. However, under high levels of dependence changes in the CCS coverage has a big impact on the precision of the estimates.

D3.2 Unfortunately, in order to draw firmer conclusions about the robustness of each alternative sample size to changes in the CCS coverage, further simulations to complete the RRMSE and Bias would be necessary. However, due to time constraints this was not possible within the given timeframe, although the simulation are ongoing.