# The Demographic Impact of HIV/AIDS in Botswana: Modelling the impact of HIV/AIDS in Botswana

Submitted by the Centre for Actuarial Research (CARe)

October 2006

**Suggested citation:**

Dorrington R E, Moultrie T A and Daniel T (2006) The Demographic Impact of HIV/AIDS in Botswana. Gaborone: UNDP and NACA, Botswana.

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# EXECUTIVE SUMMARY

This report is one of the deliverables in a tender awarded to the Centre for Actuarial Research (CARe) at the University of Cape Town by the National AIDS Co-ordinating Authority (NACA) and the United Nations Development Programme, Botswana, to investigate the impact of HIV/AIDS on the population of Botswana.

The Terms of Reference included reviewing the previous report on the subject (done by Abt Associates in 2001); establishing a preferred model to be used in the investigations; to perform a series of population projections for the population of Botswana covering at least the period up to 2021; and to assess the impact of HIV/AIDS on key demographic indicators.

The 2001 report's projections were – even in the most 'optimistic' projections – far too pessimistic given the subsequent evolution of the epidemic. Some of this can be attributed to several key weaknesses and theoretical limitations of the methodologies applied in that report, but much of the error stems from the fact that projection is, at best, an imperfect science and much has happened (for example the roll-out of ART) and much knowledge gained on the dynamics and determinants of infection in the intervening six years to have fundamentally altered our understanding of the future course of the epidemic.

In deciding on the best model to use for this project, models were first divided into those which have been used to project the impact of HIV/AIDS in Botswana but are not in the public domain and those which are in the public domain. Although, by definition, one cannot use a model not in the public domain, it was interesting to note that without exception the projections based on these models are pessimistic.

Of the models in the public domain selection was made on a number of criteria, chief amongst these being the needs of the user and the availability of the data from which to parameterise the model. After assessing a wide range of publicly available models against these criteria the ASSA2003 AIDS and Demographic model of the Actuarial Society of South Africa was selected. This model was thought to be the most sophisticated (allowing, *inter alia*, for the modelling of five of the major interventions) that can be supported by the data available. Being Excel based and regularly updated, with documentation and training, also makes it one of the models most likely to be of use to users in future. The Spectrum suite of models was considered to be an alternative but its lack of sophistication in terms of a number of aspects, in particular allowing for interventions, and the fact that it still has a number of bugs in it ruled it out of contention.

Based on our interpretation of the results, and making use of more sophisticated techniques than applied in the CSO's Analytical Reports fertility is higher than has been commonly assumed, with the TFR (total fertility rate) being around 6.6 in 1980 and still 4.3 children per woman in the year prior to the 2001 census.

Childhood mortality was also found to be significantly higher than has been previously estimated (e.g. the under five mortality rate in the year prior to the 2001 census was around 103 per thousand as opposed to 74 per thousand reported in the 2001 census analytical report). Unfortunately the indirect method that is commonly used to derive estimates of infant and under-five mortality in the absence of complete vital registration, and which appears to have worked well on the census data in the past, is severely compromised in an HIV/AIDS epidemic due to the violation of the assumption that the mortality of the mother and her children is independent.

Adult mortality is probably higher than is being measured possibly due to the disintegration of some households upon the death of a household member (resulting in there being no household left at the time of the census to report on the deaths in the reference period). We estimate that the probability of a fifteen year old not surviving to age sixty (if they suffered the period mortality rates, i.e. mortality rates in that year) was 64% in the year prior to the 2001 census.

As a result, we estimate that life expectancy in Botswana is lower than has been estimated from census data, namely around 46.5 years at the time of the 2001 census.

Owing to the higher fertility, despite the higher mortality, projections from the 1981 census population suggest that the 1991 and particularly the 2001 census undercounted the number of children. We estimate the population in 2001 to have been about 1.8 million. As a consequence of these estimates we project the population of Botswana to be higher than others have done to date. Although such a high undercount in the census is surprising, the numbers of children projected by these higher fertility rates appear to be consistent with the school enrolment data.

The single most important indicator of the extent of the epidemic is HIV prevalence. This has been chiefly monitored via surveys of women attending antenatal clinics, but in 2004 a national household prevalence survey as part of BAIS II was carried out. Comparison of estimates of prevalence of the two show the prevalence of women attending antenatal clinics to have been some 5.5% higher than that of women 15-49 in the household survey. Attempts to reconcile these two estimates indicate that there is some degree of uncertainty about the estimates from the antenatal surveys since it would appear that confirmatory testing was only done on the most recent survey results. Thus although there is some evidence that rates may have peaked this conclusion has to be treated with caution. Reconciliation, allowing for the biases that can be quantified found the antenatal results to be about 1% too high (i.e. as a measure of the prevalence of women attending antenatal clinics in Botswana) and the BAIS results about 2% too low (i.e. as a measure of the prevalence of all women aged 15-49 in Botswana).

The major conclusions about the demographic impact of HIV/AIDS are as follows:

Prevalence in Botswana is lower than was being assumed prior to the BAIS II household prevalence survey. Reconciliation of the prevalence estimates from the antenatal survey and the household prevalence survey suggest that in 2004 around 14% of the population was infected while 24% of adults aged 15-49 were infected, and that antenatal prevalence probably peaked at around 35% shortly before this.

While HIV/AIDS has had, as would be expected, significant effects on mortality in Botswana, interventions, particularly the provision of antiretroviral therapy and the PMTCT programme, have significantly reduced the number of deaths in recent years. However, this is expected to reverse quite soon with the number of deaths again increasing year on year, but at a slower rate than previously. It is thus important to set in place systems to monitor the number of deaths accurately in future.

Because antiretroviral therapy prolongs the lives of people infected with the virus the number of infected people in Botswana is expected to continue rising over the projection period. The numbers on treatment will also rise over the period reaching around 124 000 by 2021.

HIV/AIDS is not expected to have a dramatic impact on fertility in Botswana although the number of births peaked in the late 1990s and is falling as a result of the deaths of adults in the reproductive ages.

Under five mortality peaked around 1999 and is expected to continue falling in future, while adult mortality peaked around 2002 and is also expected to fall gradually in future.

As a result of the peaking of the mortality rates life expectancy has bottomed (at around 45.5 years which, although lower than the CSO's estimate, is higher than many international agencies are projecting) and is now increasing very gradually.

And also contrary to most other projections the population of Botswana is expected to continue growing, albeit at a somewhat lower rate than in the past. As a result of this and the provision of ART the number of Batswana infected with HIV is projected to continue growing, reaching more than 350 000 by 2021.

The timing and magnitude of the epidemic varies considerably between sub-districts with prevalence of adults (15-49) ranging from less than 15% to over 35%. Not surprisingly the largest numbers of infected are found where there are concentrations of people, mainly, urban areas (which are also probably those best providing ART).

In order to explore the sensitivity of the model to certain assumptions and to compare the results of the model (default scenario) against what might have been without HIV/AIDS a number of scenarios were run. These comprised: the no-AIDS (S0), default (S1), default with no ART (S1.1), default allowing for behavioural change for those routinely tested for HIV (S1.2) and default with longer survival on treatment (S1.3).

Unsurprisingly, HIV/AIDS under all AIDS scenarios has a significant impact on the population, with the total being nearly 18% lower by 2021 than it would have been in the absence of the epidemic, the number of deaths doubling, and the number of orphans increasing more than fourfold.

In terms of the AIDS scenarios the most surprising result is possibly how similar the results were for the different scenarios in many instances, with the major differences being in terms of the numbers infected and dead between the no ART and longer survival on treatment scenarios. Deaths due to AIDS would currently be some two-thirds higher without ART than under the default scenario, and some 25% lower if people survive twice as long under treatment than is assumed in the default scenario. But the gains of a longer life expectancy on treatment come at a cost. Doubling the number of years survived on ART would lead to an increase of about 60% in the number on treatment by 2021.

# GLOSSARY OF TERMS USED

**Acquired immune deficiency syndrome (AIDS):** a collection of illnesses that occur in the late stages of HIV infection, when the patient's immune system has been severely weakened by the virus. Common AIDS-defining illnesses include extrapulmonary tuberculosis, PCP (a type of pneumonia) and wasting syndrome. In the absence of treatment, most individuals die within a year or two of the first AIDS-defining illness.

**Antenatal clinic (ANC) survey:** a survey of HIV prevalence in pregnant women attending antenatal clinics.

**Antiretroviral therapy:** therapy which prevents HIV from replicating, thus bringing about a reduction in the HIV viral load and a restoration of the CD4+ count. Early antiretroviral regimens consisted of only one or two drugs (monotherapy and dual therapy respectively), but since the development of new classes of drugs in the mid-1990s, more effective regimens of three or more drugs (highly active antiretroviral treatment, or HAART) have been introduced.

**ASSA AIDS and Demographic model:** a mathematical model developed by the Actuarial Society of South Africa (ASSA) to simulate the spread of HIV in Southern Africa, and the demographic impact of AIDS.

**Asymptomatic:** not experiencing any signs of infection.

**CD4+ count:** a measure of the strength of the immune system. A healthy adult would usually have a CD4+ count of >800/μl, while an adult sick with AIDS would typically have a CD4+ count of <200/μl.

**Doyle (or Metropolitan or Metropolitan Doyle) model:** a model of the HIV/AIDS epidemic in South Africa. It was developed by Peter Doyle of Metropolitan Life, and was a precursor to the earliest ASSA AIDS and Demographic model.

**Enzyme-linked immunosorbent assay (ELISA):** a test commonly used to diagnose HIV infection. The test is based on the detection of antibodies to HIV, and will therefore yield negative results in the first few weeks of HIV infection, when the individual has not yet started to produce antibodies to the virus.

**Highly active antiretroviral treatment (HAART):** See 'Antiretroviral therapy'. HAART regimens have been shown to reduce AIDS mortality rates by between 70 and 90%.

**Human immunodeficiency virus (HIV):** a virus which destroys the human immune system by fusing with human immune cells with CD4 receptors, and ultimately bringing about the destruction of these cells. The major mode of transmission is through sexual contact, but the virus can also be transmitted through injections with contaminated needles, through blood transfusion and in the process of childbirth and breast feeding.

**Incidence:** the rate at which new infections occur. The HIV incidence rate in year t would be calculated as the number of new HIV infections in year t, divided by the number of individuals uninfected with HIV at the start of year t.

**Information and education campaigns (IEC):** campaigns to increase awareness of the modes of HIV transmission, the consequences of HIV infection, and the methods individuals can employ to reduce their risk of infection.

**Male circumcision (MC):** removal of the foreskin of the penis. Studies have shown that this can significantly reduce the risk of HIV and other STDs.

**Microbicide:** a cream that a woman can apply intravaginally in order to reduce her risk of sexually transmitted infection. No microbicide product has yet been shown to be effective in reducing susceptibility to HIV, but roughly 20 products are currently being tested in clinical trials.

**Opportunistic infection (OI):** infections which occur in the late stage of HIV disease, when the immune system has been severely weakened. Examples are extrapumlonary tuberculosis and PCP (a type of pneumonia).

**Polymerase chain reaction (PCR):** a genome detection method, highly sensitive in detecting HIV. Unlike the ELISA, it tests for the presence of HIV, not the presence of antibodies to HIV.

**Prevalence:** the proportion of the population with a particular infection. Not to be confused with incidence.

**Prevention of mother-to-child transmission (PMTCT):** programmes which reduce the risk of mother-to-child transmission of HIV, through the provision of short courses of antiretroviral treatment to the mother and infant before and after birth, and through counselling on infant feeding options (formula feeding or exclusive breastfeeding is usually promoted).

**Prophylaxis:** treatment to prevent the onset of common OIs in HIV-positive individuals with low CD4+ counts. Examples are cotrimoxazole and isoniazid.

**Routine HIV Testing (RHT):** Testing of people presenting at medical facilities for routine health care for, for example, antenatal, tuberculosis or sexually transmitted infections care.

**Sensitivity:** the probability that a diagnostic method detects infection in an infected individual

**Seroconversion:** the time at which an individual begins to produce antibodies to a particular pathogen, detectable on antibody tests

**Sexually transmitted disease (STD) or infection (STI):** infections such as syphilis, genital herpes, gonorrhoea, chlamydia, trichomomiasis and chancroid, which are transmitted mainly through sexual contact, and which can cause symptoms such as genital ulcers and genital discharges. These infections have been shown to increase the risk of HIV transmission, and improvements in the treatment of these infections are therefore important in the prevention of HIV.

**Specificity:** the probability that a diagnostic method produces a negative result in an individual who does not have the infection of interest. The false positive rate is one minus the specificity.

**Spectrum:** an HIV/AIDS model used by UNAIDS in deriving its estimates of the global distribution of HIV. The model has a number of components, which can be used to assess, for example, the demographic impact of HIV/AIDS and the potential impact of various prevention and treatment strategies.

**Viral load:** a measure of the concentration of HIV in either blood plasma or other specimens (e.g. semen). It determines both the rate of decline in the CD4+ count and the infectiousness of the HIV-positive individual.

**Viral subtype:** There are two HIV types: HIV-1 (the most common) and HIV-2 (which occurs almost exclusively in West Africa). Within the HIV-1 type, there are three groups: M, N and O (the latter two being very rare). The HIV-1 group M HIV strains are divided into 10 subtypes (A-H, J and K). In the developed world, subtype B is dominant, while in southern Africa, subtype C is dominant.

**Voluntary counselling and testing (VCT):** a service provided to individuals wishing to learn their HIV status. It includes pre- and post-test counselling, and has been shown to lead to significant changes in sexual behaviour in individuals with positive test results.

**WHO clinical staging system:** a method for categorizing HIV-infected individuals according to the severity of their disease. Four stages are defined, and individuals are always categorized according to the most severe symptom they have experienced thus far. Stages 1 and 2 are relatively asymptomatic. Illnesses defining of stage 3 include oral infections, recurrent vulvovaginal candidiasis and diarrhoea. Stage 4 corresponds to clinical AIDS, and includes conditions such as Kaposi's sarcoma, extrapulmonary tuberculosis and cryptococcal meningitis.

# ABBREVIATIONS USED IN REFERRING TO DATA SOURCES

| | |
|---|---|
| ASSA | Actuarial Society of South Africa |
| BAIS: | Botswana AIDS Impact Survey |
| BDS: | Botswana Demographic Survey<br>BDSYY: BDS carried out in year YY<br>BDSYYR: official/reported estimates from this survey |
| BFHS: | Botswana Fertility and Health Survey<br>BFHSYY: BFHS carried out in year YY |
| CSO: | Central Statistics Office<br>CSO1991: the 1991 census<br>CSO2001: the 2001 census<br>CSOYY_s: the YY census, males if s=m or female if s=f |
| UNPD: | United Nations Population Division |
| UNAIDS: | United Nations AIDS |

# CONTENTS

# 1 INTRODUCTION

This report has been prepared by the Centre for Actuarial Research (CARe) at the University of Cape Town for the National Aids Coordinating Agency (NACA) and the United Nations Development Programme (UNDP) in Botswana. The report covers the results of the Centre's investigations into the possible impact of HIV/AIDS on the population of Botswana over the coming decades. In order to keep this report as accessible as possible, we have endeavoured to relegate technical material and detailed output to report's nine appendices. Readers requiring more detail than in the main body of the report s will find more detail there.

Part of the brief was to appraise the previous assessment of the demographic impact of HIV/AIDS prepared for the Government of Botswana by abt Associates in 2000. This is covered in Section 2 with further analysis and details in Appendix 1. A second aspect of the brief was to describe the mathematical demographic and epidemiological models that are available to assist with understanding and interpreting the impact of HIV/AIDS on a population. This analysis, together with justifications for the choice of the model used, is presented in Section 3 (and Appendices 2 and 3).

Section 4 describes the principal demographic parameters (those relating to fertility, mortality, migration and the base population for the projection) required for use in any projection of a population. Extensive details on the investigations pursued, and the results therefrom, are contained in Appendices 4 (fertility); 5 (mortality); and 6 (migration, and the establishment of a base population).

Section 5 (together with Appendix 7) interrogates the HIV prevalence data for Botswana made available to us. Section 6 (and Appendix 8) describes the manner in which allowance is made for interventions into the course of the epidemic, historically and going forward.

Section 7 (with more detailed tables in Appendix 9) presents some results from the modelling exercise. However, this report is meant to give an overview of the modelling process and its results, and a far greater range of output is available from the models (which have been provided as part of this project and will be made publicly available) than can realistically be presented in this report. The interested reader is therefore encouraged to run the models for him- or herself to better understand the results from the modelling exercise, as well as the possible future implications of the epidemic on the population of Botswana.

Because of the volume of output that can be extracted from the model, and the attendant broad array of conclusions that can be drawn from the results available, it would be foolish for this report to attempt any detailed summary of suggested conclusions or implications from our investigations. Again, the real value of the model lies in the interpretation of its output by local experts on the ground. Accordingly, the conclusions set out in Section 8 provide an overall summary of what has been achieved, and offers a very high level summary of the anticipated effects of HIV/AIDS on the population of Botswana in the coming decades. This section also offers an assessment of the adequacy of the data provided for this project, and makes some tentative recommendations for improvements.

The report meets all the specific tasks as set out in the Detailed Terms of Reference specified in the original Invitation to Tender document. The table below indicates where each of the tasks is addressed:

**Table 1.1 Reconciliation of items and tasks specified in the Detailed Terms of Reference with their location in this report**

| Item | Task | Location |
|---|---|---|
| 1.1 | Review, and update as appropriate, the 2000 study on the Demographic Impacts of HIV/AIDS with particular emphasis on the methodological aspects of the study | Section 2 and Appendix 1 |
| 1.2 | Review, and update as appropriate, the 2000 study on the Demographic Impacts of HIV/AIDS with particular emphasis on the findings of the study vis-à-vis trends since the study was published | Section 2 and Appendix 1 |
| 2 | Analyse the impact of HIV/AIDS on key demographic variables such as population size growth and age structure; life expectancy; migration, mortality, fertility, dependency ratios and sex ratios | Section 7 |
| 3 | Assess the adequacy of available data for purposes of policy oriented demographic modelling and make recommendations for improvement as appropriate | Section 8 |
| 4 | Recommend, on the basis of evaluation of alternative demographic models, a demographic model for Botswana | Section 3 and Appendix 2 and Appendix 3 |

There are many in Botswana we would like to thank for their assistance in helping us with this project, not least the Botswana CSO (who generously gave access to so much data), the Botswana Ministry of Health (for the detailed data from the seroprevalence surveys and deaths recorded at hospitals), as well as the staff of NACA and the UNDP in Gaborone (for facilitating this project). We also thank all of those, as part of the Reference Group for this project, or otherwise, who have offered useful and valuable feedback on our work.

# 2 ASSESSMENT OF THE PREVIOUS REPORT

The previous attempt to assess the demographic impact of HIV/AIDS in Botswana (Abt Associates South Africa Inc. 2000) had as a stated objective “to provide Botswana with the best available projections of the demographic impact of HIV/AIDS on its population to 2010” and was a brave attempt at a time when less was known about the HIV/AIDS epidemic in general and its extent in Botswana in particular than we know now. Appendix 1 describes the methods used and the main findings of that report before comparing some of the output against empirical observations since this work was done and commenting on some of the shortcomings of the report.

In summary, the method employed was to create a version of the Metropolitan Doyle model, calibrated to Botswana epidemiological and demographic data, and to use the results from this model to estimate the prevalence of HIV among adults (aged 15-49), which was then used as input into a Spectrum epidemiological model. By and large, these estimates were derived to reproduce the antenatal results for each district and the population as a whole on the assumption that each sub-area followed the same prevalence curve over time, with the only difference being the lag of when the epidemic started in each year.

The report offers a range of projections suggesting that the population HIV prevalence was high and still rising. The authors make several important observations based on the conclusions drawn from their research. First, they suggest that their estimate of adult prevalence (that is, HIV prevalence in the 15-49 age range) “may be considered to be optimistic” (i.e. too low), because it is around 90% of the estimates derived from antenatal clinic data. In addition, they caution that the ‘best case scenario’ (S2) is also too optimistic, because the fitted levels of HIV prevalence may be lower as the result of a time lag, rather than a materially different extent of the epidemic.

Second, the authors (correctly) are at pains to emphasise the uncertainty surrounding many of the parameters used in the modelling exercises.

Third, the authors intimate that they were unable to make use of the data reported in the 1991 census on household deaths; and that neither the 1996 FHS nor 1998 DHS showed clear evidence of any impact of HIV/AIDS on mortality. Their conclusions on a rising trend in mortality were, instead, based on ‘anecdotal evidence’ and ‘problematic’ health statistics and vital registration pilot data.

Finally, although they are unable to explain why the Metropolitan model produced lower estimates than the Spectrum model, they conclude that – should experience deviate markedly from the projections produced – the source of the error is more likely to be the result of incorrectly projecting the 'timing, rather than the scale of impacts'.

Unfortunately the work suffers from a number of significant flaws, which are listed in Appendix 1 but which can be grouped under three broad headings: First, the district models were constrained to ensure that prevalence in all sub-districts peaked at the same level; second, the models were not calibrated against the death data; and, third, very little attention was paid to trying to ensure that the demographic assumptions were reasonable in the context of known features of the demography of Botswana.

As a result, the projections produced by these models already differ significantly from empirical observations or estimates derived from them. For example, the population prevalence projected by the most optimistic scenario is between 1% and 4% higher than more recent estimates; this difference is even greater for adults aged 15-59 where the *most optimistic* estimate is between 6% and 8% higher than recent empirical estimates; consequently, the most optimistic estimates of the number of deaths is some 8% higher than the best recent estimate. Clearly projecting from such pessimistic estimates can be expected to increase the deviations going forward. Thus, despite the concerns of the report's authors about being too optimistic about the future dynamics of the HIV/AIDS epidemic in Botswana, comparison of the report's projected results with those actually observed in the ensuing six years would suggest that the projections were in fact too pessimistic.

# 3 REVIEW OF MODELS AND PROJECTIONS

The purpose of this section is to evaluate the models available for projecting the demographic impact of HIV/AIDS in Botswana. The list of models considered, although extensive, is not intended to be exhaustive. In the main, we have concentrated on models that have been applied to Botswana in the past or that are publicly available.

There are three fundamental criteria to be applied in evaluating each of the models, namely; the public availability of the model; the ability of the model to meet the needs of the user; and the availability of data required as input in the model. A detailed review of the various models is presented in Appendices 2 and 3.

## 3.1 Models not in the public domain

Several models which are not publicly available have been applied to produce estimates either of the demographic impact of HIV/AIDS or of the demographic variables taking into account the impact of the disease. Although these models cannot be used for the purposes of this project, the results of such efforts are informative. Appendix 3 considers the results of projections produced by UNAIDS (2006), UN Population Division (United Nations 2005), US Census Bureau and the International Institute for Applied Systems Analysis (IIASA) (Sanderson 2002)

Although, as can be seen from Appendix 3, the models produce quite different estimates of the demographic impact of HIV/AIDS, all, in common, show it to have a significant impact which is expected to result in a decline in population numbers in future. This is consistent with the previous report but not with the estimates produced as part of the current project or with the recently released UNAIDS estimates (UNAIDS, 2006), which suggest that the impact is likely to be substantially lower.

## 3.2 Publicly available models

As far as publicly available models are concerned, the two major criteria for choosing a model were considered to be the needs of the user and the availability of data required as inputs to the model. The needs of the user include the model's ability to perform sub-national, in addition to national, projections; the model's ability to evaluate the implications of interventions on the future course of the epidemic (again, both nationally and sub-nationally); and the capacity of the model to provide sufficient detail to permit the assessment of the impact of the epidemic on the economy and health management systems. The amount of data required, and their availability are central in determining the success or accuracy of the model. Models which do not utilize all available data but rather use generic assumptions as inputs, may not provide accurate results, particularly at a sub-national level. Appendix 2 describes and assesses of the following publicly available models: ASSA2003; simulAIDS; iwgAIDS; Nagelkerke's model; and Spectrum together with EPP. The attributes of each model are described briefly below.

### 3.2.1 ASSA2003

Developed by the Actuarial Society of South Africa (ASSA), the model's primary purpose is to estimate the demographic impact of HIV/AIDS on a country's population. It is a spreadsheet-based model programmed in VBA for Excel. It projects age-by-age and year-by-year changes in an initial population profile on the basis of a number of demographic, epidemiological and behavioural assumptions. The population is divided, by sex, into three distinct age groupings: young (up to age 13), adult (14-59) and old (60 and above). Different demographic, behavioural and epidemiological assumptions are made for each group, which is then projected on a single-age, single-year basis. The adult group (assumed to be the sexually active population) is further subdivided into four risk groups differentiated by level of exposure to the risk of contracting HIV through heterosexual activity.

Assumptions are determined, where possible, on the basis of empirical evidence relevant to the population being modelled. Where this is not possible, either educated guesses are made or the assumptions are determined through calibration, the process whereby the results generated by the model are adjusted to be consistent with observed data such as the antenatal prevalence figures.

The model allows for the effect of interventions (prevention and treatment programmes) on sexual risk behaviours, probabilities of HIV transmission and HIV survival. Currently, five interventions are modelled:

- improved treatment for sexually transmitted diseases (STDs);
- information and education campaigns (IEC) and social marketing;
- voluntary counselling and testing (VCT);
- prevention of mother-to-child transmission (PMTCT); and
- anti-retroviral treatment (ART).

The model produces various detailed output. This includes, but is not limited to, the numbers of people in each sex/risk group/HIV classification and in total; the number of people sick with AIDS; the number of deaths due to AIDS and other causes, separately; HIV prevalence rates among the different risk groups; HIV incidence rates; mortality statistics including life expectancy; numbers of people accessing prevention and treatment programmes; and the number of adults and children in each different stages of HIV disease. Each of these outputs can be generated for individual ages and years. The model is thus highly flexible, and further, it can be easily customized to produce any additional outputs that can be derived from the underlying data.

The rate of spread of the infection is controlled by assumptions about the amount of sexual activity and the probability of infection. Furthermore, an individual's infectiousness is assumed to vary according to the duration of the infection and whether or not the individual is on ART. Sexual behaviour, in turn, is modelled on the basis of a combination of the following components:

- the probability that a male partner is from a particular risk group;
- the probability that a female partner is from a particular risk group;
- male-to-female transmission probabilities per sexual contact for various combinations of risk group encounters;
- female-to-male transmission probabilities per sexual contact for various combinations of risk group encounters;
- the number of new partners per year and the number of contacts per new partner per year;
- condom usage for each risk group by age;
- the effectiveness of condoms; and
- relative frequencies of sex, frequency of condom use and levels of HIV infectiousness, in different stages of HIV disease.

The median term to death of HIV-infected individuals, HIV survival, is assumed to differ according to the age at which an individual is infected. Those infected at younger ages are assumed to survive for longer in an asymptomatic state than those infected at older ages. Survival after infection is further split between six identified stages of the disease. The first four correspond to the WHO Clinical Staging System, namely, acute HIV infection; early disease; late disease and AIDS. The fifth represents individuals receiving Highly Active Anti-Retroviral Therapy (HAART), and the sixth represents individuals who have discontinued HAART. The time spent in each of the first four stages and the sixth is assumed to follow a Weibull distribution. In the fifth stage the probability of discontinuance or death is the same for each year except the year in which treatment begins, when it is substantially higher.

### 3.2.2 SimulAIDS

The model was developed by INSERM U88 (Paris) in collaboration with the School of Public Health in Kinshasa (Zaire) and Tulane University (USA). It is a simulation model of the transmission dynamics of HIV infection and of other sexually transmitted diseases in populations where HIV infection is predominately heterosexually transmitted.

SimulAIDS is stochastic and micro simulation in nature, and characteristics are therefore determined separately for each individual in the population. More than 100 input parameters are required, which can be divided into seven groups, namely, demographic; general sexual behaviour; infection through social contact; infection through non-sterile injection; infection through blood transfusions; mother-to-child transmission: and prognosis for infected individuals. The time-step between each iteration in a particular projection is usually 1 to 5 days. Furthermore, being stochastic, the model must be run hundreds, if not thousands, of times in order to determine the distribution of possible results.

The demographic parameters are assumed to be independent of the level of HIV infection. In addition, mortality rates and fertility rates are assumed to be constant over time. Thus the model is not suited for long-term projections. The model can and has been adapted to include intervention strategies to determine their effectiveness in fighting the spread of the epidemic. Examples of interventions which have been modelled are improvements in STD treatment and health seeking behaviour for STDs, reduction in the rate at which 'one-off' partnerships occur and increases in condom use with 'one-off' partners. The model has also been used to assess the potential impact of HIV vaccines.

Correctly, HIV infectiousness is assumed to be very high in the first few weeks of infection, then drops to low levels for most of the duration of infection, before increasing again a few months before progression to AIDS (in most cases, sexual activity is assumed to cease after this). The model also allows for the simulation of other STDs and for their effect on susceptibility to HIV infection. Three types of partnerships are modelled in SimulAIDS: long-term (marital) partnerships, short-term partnerships and 'one-off' relationships (involving a single sex act). Individuals are assumed to be less likely to engage in 'one-off' and short-term relationships once they are married, but after controlling for marital status, rates of partnership formation (and condom use) are assumed not to be related to age. Different users have assumed different lengths of survival but in most cases the HIV survival time is split into four stages: the acute stage (the few weeks in early infection when the individual is highly infectious), the asymptomatic stage, the pre-AIDS (symptomatic) stage and the AIDS stage. The combined time spent in the asymptomatic and pre-AIDS stages is assumed to follow a uniform distribution, and the times spent in the acute stage and the AIDS stage are fixed.

### 3.2.3 iwgAIDS

The model was designed by Stanley, Seitz and Way of the Interagency Working Group. Relatively few published papers have described the model, and it has not been developed or updated since its initial creation in 1998. The impact of the epidemic can be analyzed along several demographic and epidemiological dimensions. It is a highly sophisticated deterministic model; however, the data requirements in order to successfully fit this model are substantial.

As in the SimulAIDS model, the iwgAIDS model assumes that HIV infectiousness is increased significantly during the first four weeks of infection and then reduces substantially during asymptomatic HIV infection. At the onset of the first AIDS-defining illnesses, HIV infectiousness is assumed to increase again, and (unlike the SimulAIDS model) sexual activity is assumed to continue despite AIDS symptoms. The model also allows for the simulation of other STDs, which are assumed to increase susceptibility to HIV as well as HIV infectiousness (in individuals who are co-infected with HIV and other STDs). Similar to the SimulAIDS model, the iwgAIDS model allows for three types of partnerships: long-term partnerships, short-term partnerships and 'one-off' partnerships. The model also allows for different types of sexual intercourse. The individual's age is assumed to affect the rate at which he/she changes partners, the frequency of sexual intercourse, the types of partnership formed and the types of sexual intercourse. Interventions can be allowed for directly and their impact on the epidemic assessed. The time from HIV infection to death is split into three phases: the acute phase (lasting four weeks), the pre-AIDS phase and the AIDS phase.

### 3.2.4 Nagelkerke's model

This model was developed for the purpose of assessing the relative merits of different HIV prevention and treatment strategies. The model has relatively few input requirements. It is programmed in ModelMaker and has been described in detail by Nagelkerke *et al* (2001). The model is deterministic, and works by splitting the population into a number of 'compartments' (representing different levels of risk behaviours, different sexes, different HIV disease stages and different HIV strains). The demographic assumptions required are minimal and include only the initial size of the population in each compartment, at the start of the epidemic, a constant (with respect to both age and time) non-AIDS mortality rate (assumed to be 0.03 when the model was applied to Botswana), and the rate at which individuals enter the sexually active population (again assumed to be 0.03 in Botswana).

Although the model is described in more detail in Appendix 2, the lack of demographic sophistication makes the model inappropriate for population projection purposes or assessing the demographic impact of the epidemic.

### 3.2.5 Spectrum plus EPP

Spectrum is a compiled Windows-based suite of programs to assist policymakers in deciding policy questions related to population dynamics. It was developed and is maintained by The Futures Group International (recently changed to The Futures Institute). The system consists of a number of components, of which DemProj (a cohort-component population projection package) and AIM (an AIDS impact module) are of most interest for our purposes. In order to project the demographic impact of HIV/AIDS, a user must first use DemProj to produce a population projection that does not take HIV/AIDS into account, and then apply AIM to incorporate the impact of HIV/AIDS. AIM derives from a series of prevalence rates of HIV among adults (males and female 15-49 combined) for the whole projection period from the start of the epidemic, the numbers infected by sex and age and hence the number of new infections each year. In other words, the prevalence produced by the model is – in fact – an input into the model. This is the major conceptual limitation of the model. The UNAIDS/WHO Reference Group on Estimates, Modelling and Projection has developed a software package, EPP, (compiled in Java) for fitting a curve to observed prevalence rates from a country which is then used to extrapolate the prevalence rates forward.

As inputs, DemProj requires a base population; past and future total fertility rates; life expectancies at birth; and numbers and age distribution of net immigrants. In addition, the user has to choose from a set of standard mortality and fertility tables the one with the 'shape' closest to that of the country being modelled. Where users are less certain of these input requirements, the software allows users to make use of "Easy Proj" which constructs a projection using estimates based on the UN Population Division's most recent projections for the country as inputs. However, recent research has shown some significant flaws in these input estimates. The software also allows for one to make use of user-defined 'shapes' of fertility and mortality rates by age, although in the case of mortality this involves editing two of the files and is not recommended for the novice user.

Although DemProj projects the population by single years and in single years of age the base population, fertility, mortality and migration are for the most part in five-year age groups and single year rates and numbers have to be derived from these data.

In essence, AIM estimates the number of AIDS deaths from the prevalence rates through various assumptions about the ratio of female to male prevalence, the ratio of prevalence rates by age, and the proportion of those infected who are expected to survive each year since infection. AIM also allows for assumptions to be made for the relationship between HIV and fertility (which is assumed to be constant over time) and for an amelioration of the impact due to the provision of ART and PMTCT. Most of these assumptions can be replaced by the user, although most users would probably be forced, through lack of country-specific estimates, to accept the default assumptions.

## 3.3 Comparisons and conclusions

This section highlights some of the features of the various models reviewed, and weighs them against the two fundamental criteria that users should seek to satisfy themselves of before choosing one model over another.

### 3.3.1 Needs of the user

The needs of the user include sub-national, in addition to national, projections, the implications of interventions on the future course of the epidemic and sufficient detail for assessing the economic impact of the epidemic and for health management.

All these needs are easily satisfied by the ASSA2003 model. Sub-national projections are easily produced. Furthermore, the implication of interventions on the future course of the epidemic are easily determined as interventions are allowed for directly. In addition, the ASSA model is highly flexible and easily customized to produce additional output for assessing the economic impact of the epidemic and for health management

SimulAIDS is likely not be appropriate for meeting the needs of the user as simulation models are difficult to apply to populations of more than 10 000 to 20 000 individuals. Thus, output produced by this model may not be of sufficient quality for assessing the implications of interventions on the future course of the epidemic. However, this model is able to produce various detailed output.

Similar to the ASSA2003 model, iwgAIDS and Spectrum/EPP also may satisfy the needs of the user. The impact of the epidemic can be analyzed along a number of demographic and epidemiological dimensions. Furthermore, interventions can be allowed for directly (if somewhat crudely in the case of Spectrum/EPP) and their impact on the epidemic assessed.

Nico Nagelkerke's model, however, has limited use from a demographic point of view as it is not structured by age. Thus, sufficient output for assessing the economic impact of the epidemic and for health management is likely not to be available.

### 3.3.2 Availability of data

The ASSA2003 model requires various demographic, epidemiological and behavioural assumptions. A great deal of data are required for determining these assumptions, however, these assumptions are justifiable for Botswana and readily available from the given data.

Both SimulAIDS and iwgAIDS have a large number of parameters and it is unlikely that there will be sufficient data to allow one to estimate all these parameters.

Nico Nagelkerke's model, on the other hand, has relatively few input requirements. Furthermore, the demographic assumptions required are minimal. Thus, this model will not be difficult to parameterize given the available data for Botswana.

Spectrum's data requirements are not much different from that of ASSA, with the important exception that the user has to make assumptions about the future course of the epidemic for Spectrum but not for ASSA.

### 3.3.3 Conclusion

A number of models have been investigated, however, all but two are either over-simplified (e.g. Nagelkerke) or overly complicated (e.g. iwgAIDS). The choice is therefore between Spectrum and ASSA. The major drawbacks of Spectrum are the constraints on input (quinquennial age groups, crudeness of modelling changes in demographic parameters over time and difficulty changing some assumptions, e.g. non-AIDS mortality), lack of behavioural modelling, limited intervention modelling, and by comparison with ASSA extremely limited interface capabilities. In addition several flaws in the Spectrum model have recently come to light (Mulder and Johnson, 2005) which cast doubt on the accuracy of the model. Hence given the performance of each in terms of flexibility, transparency and usability, it is concluded that the most appropriate model for estimating the demographic impact of HIV/AIDS in Botswana is the ASSA2003 model.

It was the intention to create a set of input parameters from the ASSA model to be used in Spectrum to generate materially similar results, as a benefit to those who are already familiar with Spectrum. However, in the process of this and other work it has become clear that the DemProj and AIM components of the Spectrum suite have a number of bugs in them that make it impossible at this stage to reproduce the results from the ASSA model sufficiently closely. We are working with the author of that model, John Stover, to fix these bugs for the next version of the model and once this is complete we will parameterise it to simulate the results of the ASSA model.

# 4 DEMOGRAPHIC ESTIMATION

## 4.1 Introduction

This section discusses in turn the estimation of the various demographic projection components: fertility, (non-AIDS) mortality, and migration and base population. Full details of the methods used to derive estimates and the results thereof are contained in Appendices 4 to 6.

## 4.2 Fertility

Estimates of fertility are required, by single year of age, for each year of the projection period. Since the incorporation of HIV/AIDS into a projection of the Botswana population requires that the projection commence in 1980, this means that estimates of fertility in the country need to go back at least as far as that, and must cover – at least – the duration of the projection going forward. Further, since the model proposed projects the population of each census district of Botswana separately, this necessitates that single-year, single-age estimates of fertility are required for each of these regions, at a level of disaggregation beneath the national.

Detailed investigations were conducted to understand the trajectory of Botswana from 1980 to the present, using as much data from the country as possible, as well as official reports on censuses and surveys conducted over this period. These investigations are described in detail in Appendix Four.

The single biggest issue confronted in the estimation of fertility rates was that official estimates (as given in the census Analytical Reports for 1991 and 2001) were derived using a methodology that will underestimate fertility rates if children under the age of 5 are differentially undercounted in the census, a feature of the two enumerations conceded elsewhere in those same Analytical Reports. Consequently, the estimates of fertility in 1991 and 2001 (and hence all intervening years too) used in the parameterisation of the fitted model are somewhat higher than the official estimates. Fertility levels are estimated as 5.5 children per woman in 1991 and 4.2 in 2001compared to the official estimates of 4.2 and 3.3 children per woman in the same years.

Data from the 1981 census were not available, so all that was possible was to use published data as inputs into a Relational Gompertz model (unavailable in 1981) to derive an estimate for 1981 of 6.5 children per woman; somewhat lower than the 7.1 suggested in the 1981 census Analytical Report, but roughly equivalent to the 6.6 suggested for 1981 in the 1991 and 2001 reports, although we have found no documentation on the provenance of this figure.

Fertility levels for each district, by individual age and single year from 1980 to 2001, were derived by interpolation from the estimates for each district in 1981, 1991 and 2001. For years after 2001, fertility levels were estimated by assuming an exponential decline in fertility thereafter, taking care to ensure that there were no significant discontinuities in the projected fertility rates. We anticipate fertility achieving replacement levels between 2015 and 2030, depending on the district being considered.

## 4.3 Mortality

Estimating mortality rates in Africa is - at the best of times - a haphazard enterprise, since few countries have reliable, let alone complete, vital registration systems, and estimates usually have to be derived either through the use of indirect questions (such as mothers reporting on the number of births and deaths of their children, or children reporting on the survival of their parents), or from deaths reported by households. Estimating non-AIDS mortality in an era of HIV/AIDS is an order of magnitude more difficult, with the results being that much more uncertain.

The methods and results of estimating mortality are described in Appendix 5. Child and adult mortality are be dealt with separately since the data available, approaches and trends in the rates differ. The results from each investigation are combined to produce a single life table for each of the years required by the projection. Following that, we turn our attention to estimating the rates for each of the census districts.

### 4.3.1 Infant and childhood mortality

The primary data on infant and child mortality are the answers to the so-called Brass questions, asking mothers to report on how many children they have borne and how many are still alive. Together with the age of the mother and some modelled relationships and assumptions (described in various texts, e.g. UN Manual X (United Nations 1983)) one is able to translate these numbers into probabilities of survival of children from birth to specific average ages and hence into infant and child mortality rates. Inspection of these data from various sources, as is shown for the under-five mortality rates in Figure A5.1[*], lead to two conclusions about the sources of data, namely that responses from the two censuses (1991 and 2001) are remarkably consistent until the early 1990s, and that, given that consistency, the responses from the other surveys produce estimates that not only are inconsistent with one another, but are all somewhat

[*] Estimates based on the responses of women in the 15-19 age group have been excluded since the mortality of their children is likely to be higher than that of the rest of the women.

lower than those from the census. On the basis of this comparison it was decided to base our estimates on the census data alone.

Unfortunately the Brass 'children ever borne – children surviving' technique produces results which significantly biased downwards in an AIDS epidemic (Ward and Zaba (unpublished) and Zaba, Marston and Floyd (2003)) and thus cannot be relied upon to produce estimates of child mortality in Botswana after about the early 1990s.

The projected non-AIDS mortality rates are based on an exponential extrapolation of the trend in the estimates derived from the 1991 census adjusted slightly in the most recent years to remove the expected influence of HIV on the mortality rates. This curve is shown in Figure A5.1. This process was repeated for the infant mortality rates, both curves fitting the data extremely closely.

In order to produce sex-specific rates, the average ratio of the sex-specific rates to the overall rates for each sex for the first three points in time (in order to avoid the impact of HIV/AIDS on this ratio) derived from the 2001 census data[*] was applied to the rates estimated from the exponential curve fitted as described above.

Rates at individual ages from 0 to 4 were derived by assuming that the force of mortality followed a hyperbolic curve with respect to age over this age range as determined by these infant and under-five mortality rates.

### 4.3.2 Non-child mortality

Deriving adult mortality rates was a complex process that involved a number of stages as described more fully in Appendix 5: estimating rates of mortality for the year prior to the census and in the intercensal period by applying the Generalised Growth Balance and Synthetic Extinct Generations methods in combination; comparing these rates against estimates derived by others (see Figure A5.2); removing the impact of HIV mortality in the early years to derive a trend in non-HIV mortality; interpolating rates at individual ages from the quinquennial rates; and finally interpolating and extrapolating these rates using exponential trends to the ultimate mortality in ASSA.

### 4.3.3 Full life tables and projected non-AIDS mortality rates

The rates at all ages were produced by blending the infant and child mortality rates with the adult mortality rates from ages 10 and upwards. Inspection of the 'reduction factors' implied by the fit of the empirical data up to 1996 suggested that if these were used to project the rates into future

[*] This was necessary since the 1991 census did not ask about the sex of the child.

years then male mortality would eventually fall below the female mortality. Thus it was decided to project both rates using the average of the male and female reduction factors for 1981-1996.

### 4.3.4 District non-AIDS mortality rates

Full life tables were produced by first estimating indices of childhood mortality (${}_5q_0$) and adult mortality (${}_{45}q_{15}$) for each district and then using these and Brass's relational model, with the national life table as standard, to generate full life tables for each district.

Under-five mortality rates were estimated for both sexes combined for each district as reported by women 35+* (i.e. in the period 1986 to 1993) in the 2001 census data, using the same method and standard table as used to produce the national rates. These rates were then averaged and compared to the average of the national rates for these women. From this a scaling factor was derived which as assumed to apply to the non-AIDS mortality rates from 1980 to 1996 for both boys and girls.

Although the range in estimates was greater than expected (from about 50% to 150% of the national rates this did not seem to be a function, particularly, of the sample size and so it was decided to accept these estimates except for Ghanzi and the Kgalagadi Game Reserve individually and instead estimates based on combined data were used for these sub-districts.

Since adult mortality is based on the deaths reported by households to have occurred in the previous year or so, the only data not to be significantly influenced by HIV/AIDS was that from the 1991 census. Thus these data were used to produce estimates of adult mortality (${}_{45}q_{15}$) with the intention of then estimating scaling factors from a comparison of the district-specific rates with those of the country as a whole on the assumption that there was no reason to suppose households in one district reported deaths better than households in any other district. Unfortunately, the sample sizes in some sub-districts were too small to produce reliable estimates and rates for these sub-districts had to be approximated by regressing the estimates of male and female rates on the rates of both sexes combined for those sub-districts (the majority) where the results looked reasonable and applying the regression to all sub-districts where the rate for males and females combined looked reasonable. Mortality rates for other sub-districts were approximated from the rates for neighbours in the district. These rates were used to derive scaling factors (the ratio of these rates to those for the country as a whole) and these were used to scale the national non-HIV adult mortality for each sub-district.

* These older women were chosen to limit the impact of HIV/AIDS on the results.

## 4.4 Migration

For most countries international migration is a relatively small component of the national demographic balancing equation. This is not the case in Botswana which has experienced non-trivial flows over the 20 years from 1981 to 2001. In addition to this it is likely that, in common with South Africa, the country will have experienced its share of hidden migration from Zimbabwe, particularly in recent years. Unfortunately, as is the case with most countries, particularly developing countries, it is extremely difficult to document accurately these flows of migrants.

For this project we adopted a two-stage approach. The first stage was to estimate the flow of immigrants net of emigrants by sex and age over each of the intercensal periods by making use of the difference in the 'stock' of each of the foreign-born population resident in Botswana, and of the Batswana population resident outside the country. The second stage was, as part of the reconciliation of the census populations, to check if there was an excess in the 2001 census that could be reasonably explained by hidden migration (migrants being counted in the census as being locals[*]) – if so, then the numbers of immigrants could be increased by this shortfall.

The number of surviving immigrants less the number emigrants in five-year age groups up to the open interval 75+ as at the end of the intercensal period were derived as the difference between the number foreign-born less the number of absentee Batswana at that age in the second census, less the same figure ten years younger in the first census. To these numbers were added back the number that might have been expected to have died before the second census on the assumption that migration took place uniformly over the intercensal period.

Numbers of migrants at individual ages were derived from these numbers using Beers interpolation (Shryock and Siegel 1976) and then converted to numbers for each of the years on the assumption that migration occurred uniformly over the intercensal period (or birth, if this occurred in this period).

From the reconciliation of the South African 2001 and 1996 censuses it appears as if most hidden migration to South Africa takes place in the 20-29 year age band. However, in the case of Botswana, although the 2001 census exceeds the population projected from the census in 1981 this is at ages over 30 and in the case of the 35-39 age group appears to reflect a shortfall in the 1981 census. Thus it was decided to make no adjustment to the migration figures to account for hidden migration.

[*] As there is no information of undocumented immigrants who were not counted in the census no adjustment could be made for them.

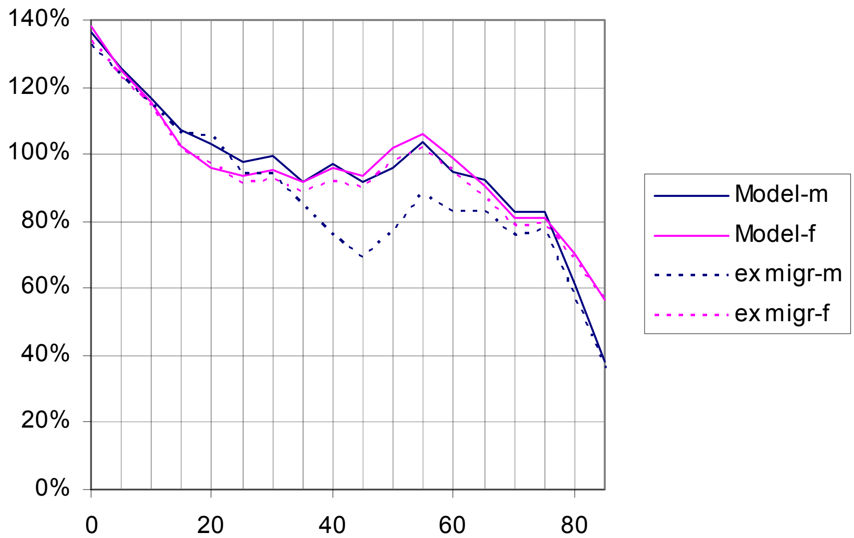
## 4.5 Base population

In order to allow for the development of the disease from the start of the epidemic, the model requires a base population for a year in the early 1980s. 1980 was chosen to facilitate comparability with other models as well as being comfortably before or near the start of the epidemic. Thus it was decided to start with the 1981 census back-projected one year, which gave rise to the first problem – there are at least four different (some substantially different) tables purporting to be the enumerated population from this census. Only one of these, that from the data held by ACAP apparently based on a 25% sample, provided numbers by individual ages, and although the total is not exactly 25% of the totals for the other sources, and the numbers are particularly different for age groups 75 and above, it was used to derive a distribution of the population by age for each sex.

A full description of the strategy used to derive the base population is given in Appendix 6 but in brief the approach was to derive an estimate of the population in 1981, and to back-project that to 1980 to create an initial base population. Projections from this initial base population were then compared to the census counts in both 1991 and 2001 and these comparisons used to adjust the base population so that the estimates produced by the model most closely corresponded to all three censuses.

Figure 4.1 shows the comparison of the projected population against the census in 2001.

**Figure 4.1 Ratio of the projected population to the census population in 2001**




(Dotted lines represent the ratio ignoring migration; m – male, and f – female)

Three things are apparent from this figure. The first is that the census appears to have undercounted, quite significantly, the number of children under age 20 for males and 15 for females. The second is that there appears to be, as was mentioned above, quite extensive age exaggeration. The third is that migration is significant particularly in the case of males. Of course in terms of numbers the difference at the young ages swamps all other differences

### 4.5.1 Sub-districts

The base populations and migration numbers for each of the census sub-districts were determined in several stages. The first was to model the national population using the national base population, fertility, mortality, migration, epidemiological and intervention assumptions. The second stage was to derive estimates of the population by age and sex for each district for each year from 1980 to 2020, using the age distributions in 1991 and 2001 as a starting point and ensuring that the sums of the numbers in the sub-districts at each age were consistent with the national total at that age. The third stage was to produce prototype models for each of the sub-districts using the national epidemiological and intervention assumptions but district demographic and prevalence assumptions and the base population derived as part of the second stage for 1980. Migration was set to zero. Each model was then calibrated to reproduce as reasonably as possible[*] the observed antenatal prevalence rates for the particular sub-district.

The fourth stage was to estimate for each sub-district the number of migrants by sex and age for each year. This was achieved by using the sub-district models to project the population one year later assuming no migration for that year and then differencing these numbers from those derived in the second stage. These migrants were then added to the model and the population projected forward to the next year, etc. As a check, the sum of the sub-district migrants had to be the same as the national net number of migrants.

The final stage was to incorporate sub-district intervention assumptions and to refine the calibration for each district allowing for this and migrants, and to refine the calibration of the national model to ensure that it produced as close a fit to the sum of the district models as possible.

[*] For a number of sub-districts the observed antenatal results did not conform to a clear pattern making calibration crude at best.

# 5 HIV PREVALENCE

## 5.1 Introduction

Data on the prevalence of HIV are the single most important indicator of the extent of the epidemic in a population. For the purposes of modelling the demographic impact of the epidemic in Botswana there are two principal sources of prevalence data. The first is the national survey of selected public antenatal care clinics which has been carried out virtually every year since the early 1990s and covering most of the census sub-districts from 2001 (Ministry of Health 2005; National AIDS Coordinating Agency (NACA) 2001, 2002, 2003). The second is the first household prevalence survey (BAIS II) carried out in 2004 (National AIDS Coordinating Agency (NACA), CSO and Other Development Partners 2005).

Unfortunately, in practice, survey data on prevalence are not without problems, and one needs to take these into account when calibrating the model to reproduce the empirical data. Thus it is necessary to interrogate the data, which is the purpose of Appendix 7.

## 5.2 Potential problems with the data

The antenatal survey data are subject to the following potential problems:

- The sites and the number tested at each site are not determined on a basis that ensures that the results will be proportionally representative of the country. However, the survey now covers enough sites for a weighted average of the prevalence of the sites to be able to produce a reasonable estimate of the antenatal prevalence of the population of the country as a whole, and its main sub-populations.
- The results could be a biased estimate of the prevalence of women attending antenatal clinics due to the fact that not every pregnant woman attends a public antenatal care clinic during pregnancy. However, this is not likely to be a significant bias since a high proportion of women attends antenatal clinics (nearly 95% of births occurred in an antenatal clinic since 2000 according to the BAIS II survey).
- The results are biased estimates of the prevalence of all women age 15-49 since only pregnant (and, by definition, sexually active) women are tested. At the younger ages (particularly below age 20) the HIV prevalence estimates can be expected to be much higher than the true prevalence in all women (many of whom would not yet be sexually active). At the older ages the bias might operate in the opposite direction, since women infected with HIV may well be less likely to bear children and hence not as likely to be included in the survey sample.
- The antenatal sub-districts are not all exactly the same as the census sub-districts.

The household prevalence data are subject to the following potential problems:

- The major problem with such surveys is what is known as the 'non-response' bias. Part of this could be simply because the survey is not of all people but confined to those who live in households, but as virtually everyone in Botswana lives in households this is unlikely to be a significant source of bias. By far the largest part of the non-response will be due to people not participating in the survey out of choice, and since this decision may well be linked to the risk of being HIV-positive it could, in surveys with response rates as low as was the case in Botswana (61%) lead to significant bias in the estimates produced by such surveys.
- The reliability of Oral Mucosal Transudate (OMT) collection testing for the virus in an African setting and of children is unknown*.

The two surveys also have the following potential problems in common:

- The samples are small and thus any estimates will be subject to a degree of statistical uncertainty.
- The lack of confirmatory testing of all surveys except the most recent antenatal survey means that the results of all except this survey will be quite uncertain but possibly biased upward.
- Neither survey covers all the census sub-districts, although the household survey is reasonably complete.
- The age distributions of the samples (and in the case of the BAIS sample, the weighted population) do not correspond with those of the census.

### 5.3 Prevalence data

Table A7.1 presents the prevalence data from the antenatal surveys by survey district over the years while Table A7.2 presents the results in census sub-districts of the household prevalence survey. The antenatal prevalence results are also presented visually in Figure 5.1. In 2005, the observed prevalence of women attending antenatal clinics ranged from around 20% in the Gantsi district to around 50% in the Selebi/Phikwe district, with national prevalence of around 35%. There does not appear to be much difference between the prevalence of HIV in urban and rural sub-districts. There is some evidence that prevalence may have peaked, with only six of the 22 sub-districts showing higher prevalence in 2005 than in 2003, however, given the lack of confirmatory testing in the pre-2005 surveys it is too early to draw firm conclusions.

Not unexpectedly, given the biases in the antenatal survey as an indicator of the prevalence of women age 15-49, the prevalence levels from the household survey are on average some 5.5% lower than those from the antenatal survey. However, somewhat unexpectedly the prevalence of HIV in women in the urban sub-districts is around 3% lower than that in the rural sub-districts The apparent contradiction of the relationship of these prevalence rates in the report

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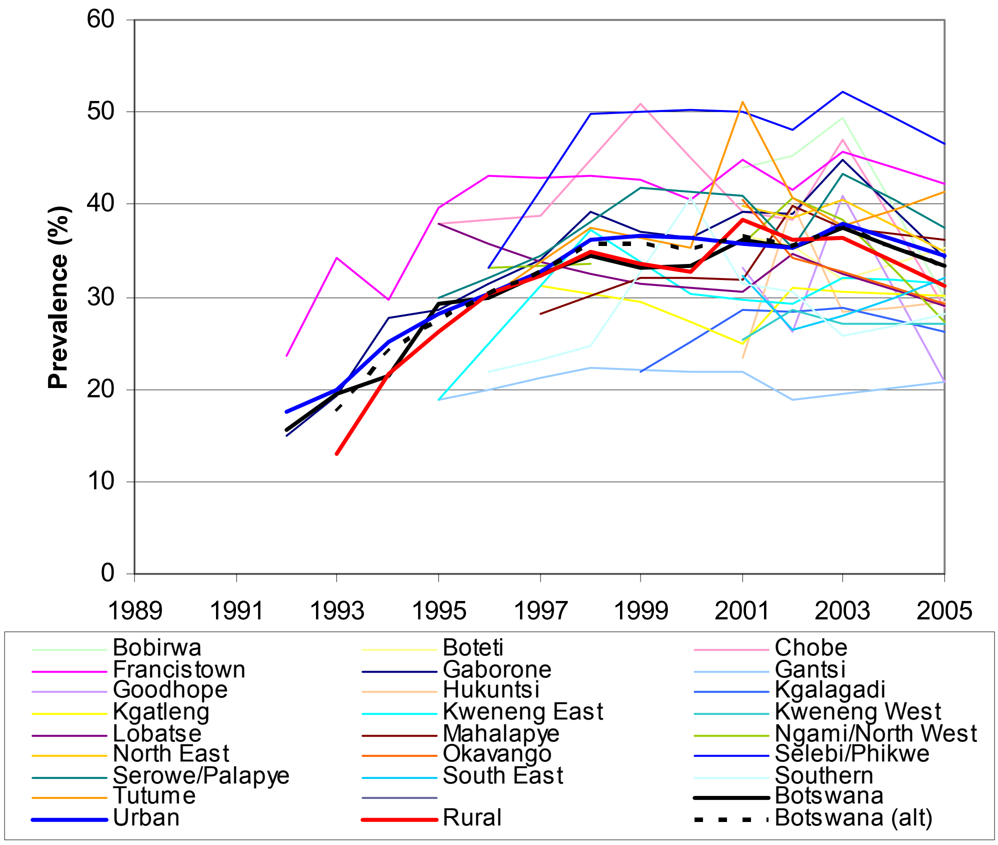
* Some studies (e.g. Nkengasong et al, 1999 and Van Rensberg et al, 1996) report specificities of 99.5% or higher, while others (e.g. Meda et al, 1999 and Louis et al, 1999) report specificities of less than 90%.in adults but there are no studies on children.

(National AIDS Coordinating Agency (NACA), CSO and Other Development Partners 2005) is probably due to the finer definition of urban and rural (separating out cities, towns and urban villages from the rest, as opposed to classifying whole sub-districts as either urban or rural).

**Figure 5.1 Antenatal prevalence by district and nationally**




## 5.4 Reconciliation of the antenatal and household survey results

In order to compare the figures from the two surveys we need to adjust for those biases for which we can. In the case of the household prevalence data the only adjustments made were to reduce the prevalence slightly for 'false positive' testing results (assumed to be 2% of the HIV negative participants), and for each district to weight the testing results by the proportion of women by age in the 2001 census[*]. On average these adjustments reduce the estimated prevalence from this survey by about 2%.

Deriving an estimate of the prevalence of all women 15-49 from the antenatal survey requires us also to adjust for the false positive results. However, before we do that we have to

[*] These are the weights used for the antenatal survey results and are surprisingly different from the weights used in the BAIS survey.

adjust for the biases by age due to the fact that the survey only measures those who are sexually active and fall pregnant. In order to estimate the extent of this bias we estimate from the BAIS survey the relationship for each age group between the prevalence of pregnant women who attended antenatal clinics to that of all women. Ideally one would wish to confine this comparison to women who attended antenatal clinic over the same period as the antenatal result are being measured, and as Bulatao pointed out in his report on population projections for Botswana (Central Statistics Office (CSO) 2005), because of the sample size it is better for this period to cover a number of years. We used the same period he chose, namely, pregnancies occurring in the period 2000-2004 (including current pregnancies). However, in order for this prevalence to estimate the prevalence that would have been recorded by the clinics at the time one needs to increase the estimate for fact that the mortality of infected women is higher than that of uninfected women and thus, a retrospective estimate derived from a household survey would underestimate the true prevalence, and for the fact that one should be considering the prevalence of a population up to four years older at the time of the survey. Making these adjustments and weighting using the 2001 census numbers produces an estimate of 35.5%, very similar to the average prevalence measured over the four most recent antenatal surveys (2001, 2002, 2003 and 2004), which is mildly confirmatory of the logic employed.

On the basis that these estimates of prevalence are a reasonable proxy for those of women in the BAIS sample who were sexually active and pregnant we are able, by comparison of these rates with those of all women in each age group, to derive an estimate of the extent of the 'pregnancy bias' (the ratio of the prevalence of all women to that of pregnant women (attending public antenatal clinics). These ratios are shown in Table A7.3.

These ratios were then applied to the antenatal prevalence for 2004 for each district (estimated as an average of the 2003, adjusted for false positives, and 2005 survey results), corrected for false positives. These results produced a weighted average estimate of the prevalence of women aged 15-49 in the population of 32%, some 4.8% higher than the weighted household prevalence corrected for false positive results. This 4.8% is thus an estimate of the maximum impact of the other, non-measurable, biases, in particular the non-response bias.

On the assumption that the true result lies somewhere in the range between the two estimates it was decided to estimate prevalence as a weighted average of the two using the size of the samples (2001-2005 for the antenatal results to give weight to the consistency of the level of results over time) as weights. This, applied to each of the sub-districts, produced an estimate of 31.3%, around 2% (absolute) above that estimated by the BAIS II survey. The prevalence of the rural sub-districts remains higher than that of the urban sub-districts but the difference has narrowed to 2.2%. These results are compared in Table A7.4.

In order to ensure that the antenatal prevalence rates are consistent with this estimate (and those derived for each of the sub-districts corresponding to the antenatal clinic sub-districts) adjustment factors were derived as the ratio of these new estimates to those based on the antenatal prevalence rates. The overall impact is to reduce the prevalence by 1% (in absolute terms) and to reduce the extent of variation between district prevalence rates slightly, as given in Table A7.5.

# 6 INTERVENTIONS

## 6.1 Introduction

The ASSA2003 model allows directly for the effect of interventions (prevention and treatment programmes) on risky sexual behaviours, probabilities of HIV transmission and HIV survival. Five interventions are modelled, namely, information and education campaigns (IEC) and social marketing, syndromic management of sexually transmitted diseases (STDs), voluntary counselling and testing (VCT), prevention of mother-to-child transmission (PMTCT) and anti-retroviral treatment (ART). Appendix 8 describes these in more detail, while a brief summary of each is given below.

## 6.2 Information and education campaigns (IEC) and social marketing

The main effect of information and education campaigns and social marketing is assumed to be to increase condom usage. The assumed rates of phase-in for these programmes have therefore been set in line with trends in the increase in condom usage.

It is assumed that behavioural change associated with these campaigns started in 1993, although undoubtedly condom usage increased from very low levels before that. This assumption is based on the date when Population Services International (PSI) started promoting 'Lovers Plus' condoms in Botswana. Furthermore, in 2003, the Government of Botswana launched an extensive condom distribution and marketing program in a direct response to deficiencies in the supply of condoms and ineffective social marketing strategies (ACHAP 2004). Hence, phase-in rates are assumed to reach a maximum after 2001.

The rates of condom usage are guided by data from BAIS I and BAIS II, although the condom usage rates reported in these surveys are incompatible with both the consistently high prevalence levels and the relatively high fertility rates.

## 6.3 Syndromic management of STDs

Improved STD treatment, through syndromic management of STDs, lowers the probability of HIV transmission, because other STDs enhance the risk of HIV transmission when present in either the HIV-negative or HIV-positive partner.

Syndromic management protocols were first introduced into the public health system in Botswana in 1992. It is assumed that syndromic management protocols were phased-in linearly over the period 1992-1996, i.e. it is assumed that by the end of 1996 all public health facilities that manage STDs followed the sydromic management approach.

### 6.4 Voluntary counselling and testing (VCT)

The Tebelopele VCT centres were first introduced in April 2000. These are the primary VCT centres. Initially, these centres were only implemented in a few districts. However, by the end of 2003, these centres were available nationally. Routine HIV testing has also been introduced, however, it has been found that individuals who autonomously seek HIV counselling and testing, through, for example, VCT centres, are more likely to modify their sexual behaviour than individuals who are routinely tested. Thus, the effects of RHT on sexual behaviour are weaker than those of VCT and the phase-in rates for VCT are set to ensure that the total number of individuals receiving VCT, according to the model, is roughly consistent with the number of first time testers at the Tebelopele VCT centres.

### 6.5 Prevention of mother-to-child transmission (PMTCT)

The national PMTCT programme was introduced in April 1999. However, it has only been available in all districts of Botswana since November 2001. According to available programme data, the proportion of women offered or which has access to PMTCT services has increased steadily from 1999.

Furthermore, the ART take-up rate is assumed to be 65%. According to programme data, this take-up rate has been fairly constant since the start of the programme and, similar to the VCT take-up rate, approximately set at the average take-up rate over the period.

### 6.6 Anti-retroviral treatment (ART)

Anti-retroviral treatment lowers the probability of HIV transmission as it lowers the concentration of HIV in the body and, hence, renders recipients less infectious. Anti-retroviral therapy has been available, in the public sector, since January 2002. However, the exact date of commencement in the private sector is unknown. Nevertheless, it is assumed that ART has been privately available since 2000. This assumption is based on the estimated number of individuals receiving treatment through the private sector during 2002.

# 7 RESULTS

## 7.1 Introduction

Below we present selected results from the model first at a national level and then by district, but before that we consider the calibration of the model to prevalence and mortality data.

## 7.2 Calibration

Figure 7.1 compares the estimates of the prevalence of those attending antenatal clinics from the model against the estimates derived from the survey of antenatal clinics. Included in the figure are the estimates of prevalence adjusted for bias in the antenatal estimates as derived from comparison with the household prevalence survey (BAIS II). Also included in the figure are target prevalence estimates prior to the survey to give some idea of prevalence levels in the early years of the epidemic. These points were derived by merging the trend in prevalence results from South Africa into those from Botswana in the early 1990s.

**Figure 7.1 Model compared to the antenatal prevalence and adjusted prevalence**

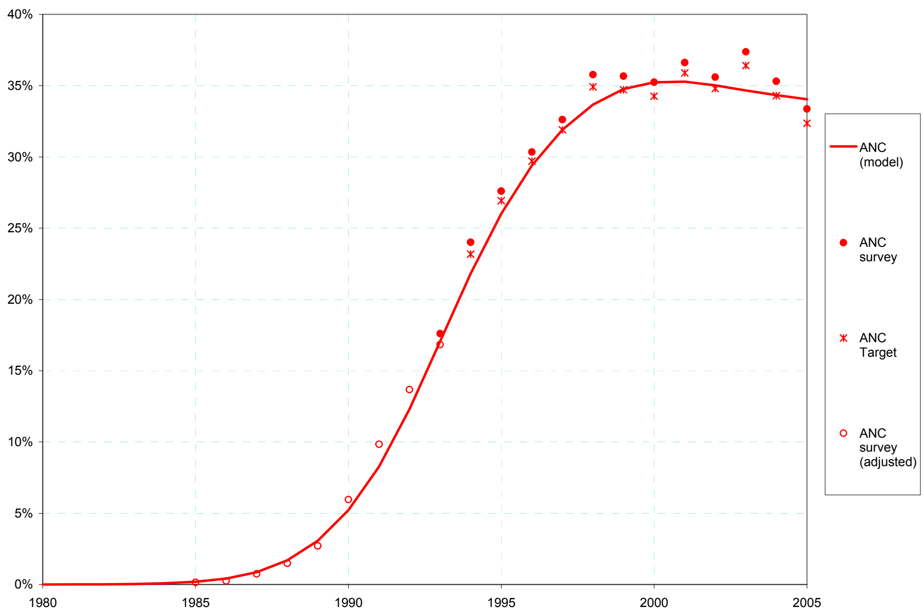



Figure 7.2 compares the probability of dying in the first five years of life produced by the model with estimates derived from various surveys. Clearly the estimates are very different, with the estimates from the model being substantially higher from 1990 than even the estimates derived from the censuses, which were used to produce the estimate of non-AIDS mortality. However, this is to be expected. The methods used to derived estimates of infant and childhood mortality

from census and survey data are extremely biased under conditions where HIV affects the mortality of both the mother (who has to report on the survival of the children) and the children (upon whose status the mother is reporting). That the estimates from the model are reasonable can be deduced by noting that if 30% of mothers are infected and a third of their children get infected and 60% of these are expected to die before age five, then the all-cause mortality rate must be 0.06 (or 60 per mille) higher than it would have been in the absence of HIV.

**Figure 7.2 Under five mortality rate (probability)**

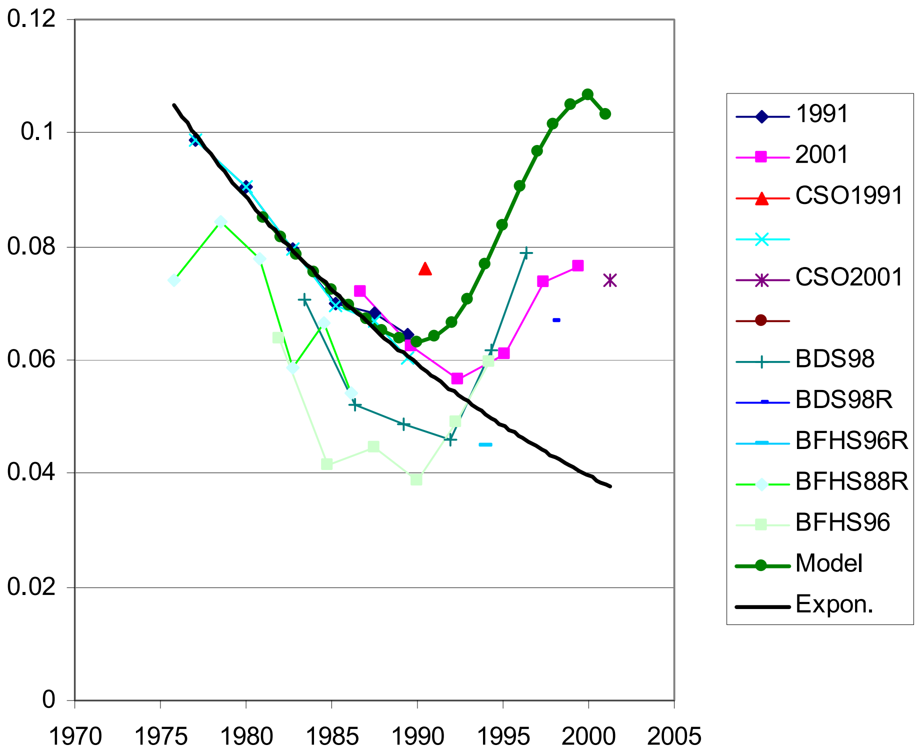
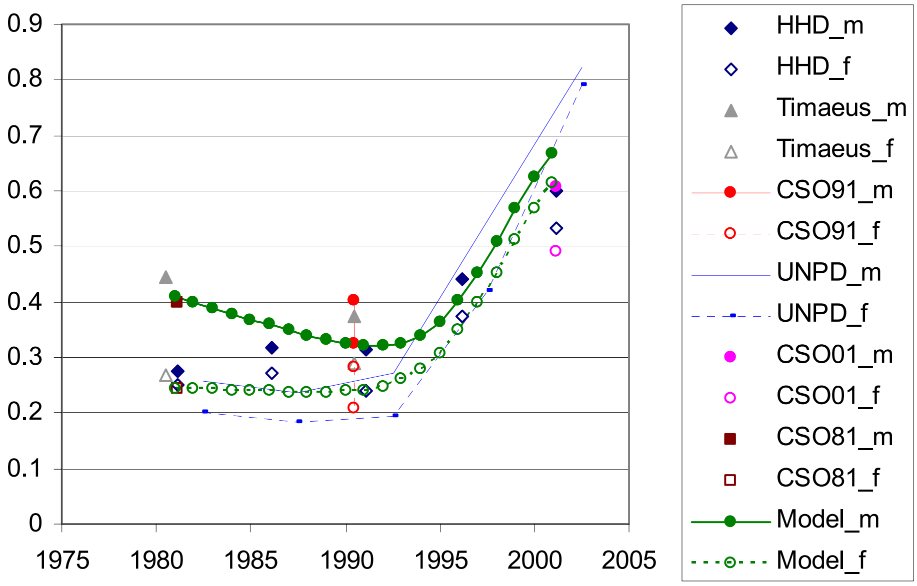



Figure 7.3 compares a summary measure of the adult mortality rate (the probability of a 15 year old dying before reaching age 60) against various estimates, including estimates derived using the census data on deaths reported by households (HHD) for males (m) and females (f). From this it is apparent that the model fit the estimates reasonably well to the mid-1990s but then exceed the estimate derived from the 2001 census somewhat, but are not as extreme as the estimates derived from the UN Population Division's projections. It is hard to see how the model can be exaggerating mortality since the assumed proportion of the population infected does not exceed that measured by the household survey and the model assumes a long life expectancy for those infected with the virus of approximately 10.5 years.

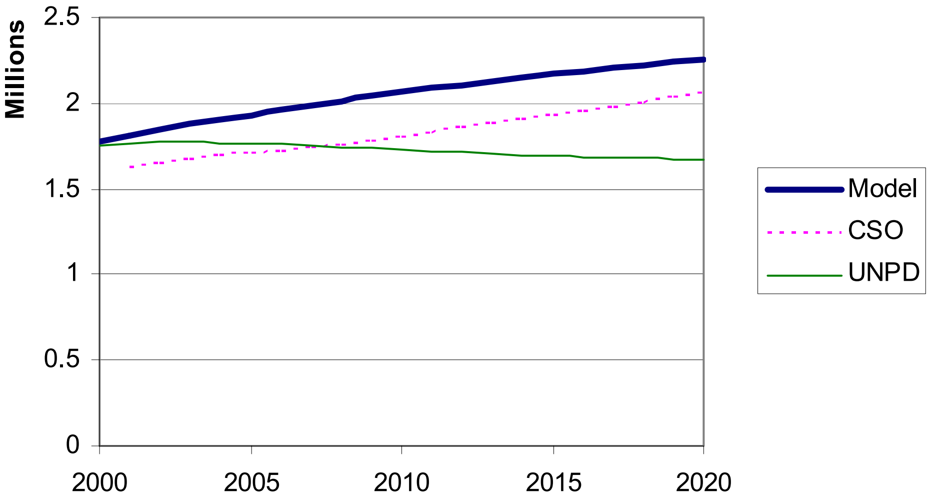
**Figure 7.3 Adult mortality (the probability of a 15 year old dying before age 60)**




## 7.3 National results

Figure 7.4 shows the projected total population compared to that produced by the CSO and UN Population Division. Although the population in 2000 is very similar in magnitude to that projected by the UN Population Division the projections diverge significantly from that point, while the model and CSO grow at very similar rates but start from different bases due to different estimates of past fertility.

**Figure 7.4 Projected population by year compared to projections by the CSO and UN Population Division**




The modelled projection is approximately 10 per cent higher in each year than that produced by the CSO mainly due to the significantly higher fertility rates estimated and hence assumed by model used for this project. The effect of this on the age distribution of the population can be seen from Figure 7.5. Although the difference between the model and the census under age 15 is uncomfortably large, the projected figures appear to be broadly consistent with the school enrolment data*, and thus are to be preferred.

**Figure 7.5 Total population by age in 2001 compared to the census and the estimate from UN Population Division 2000**

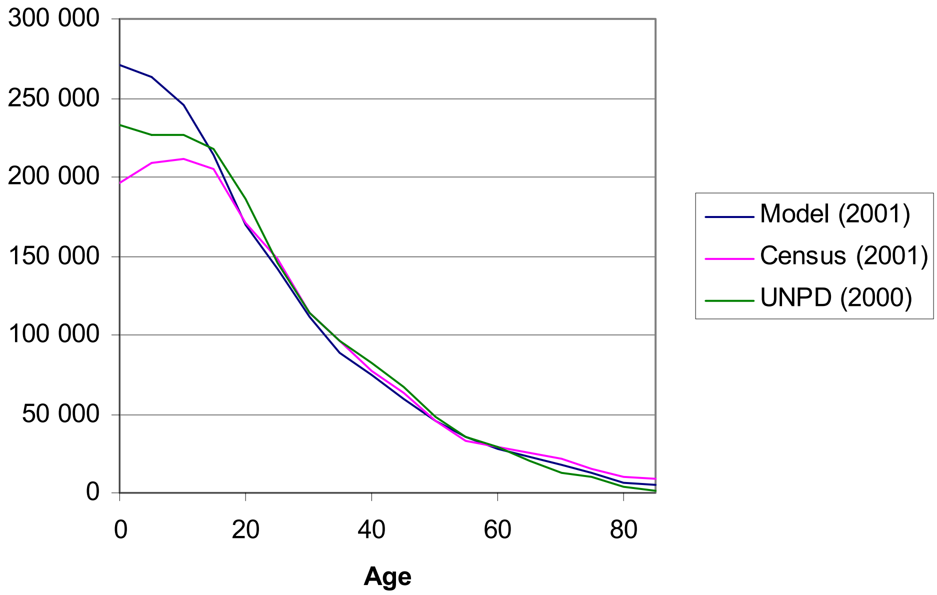
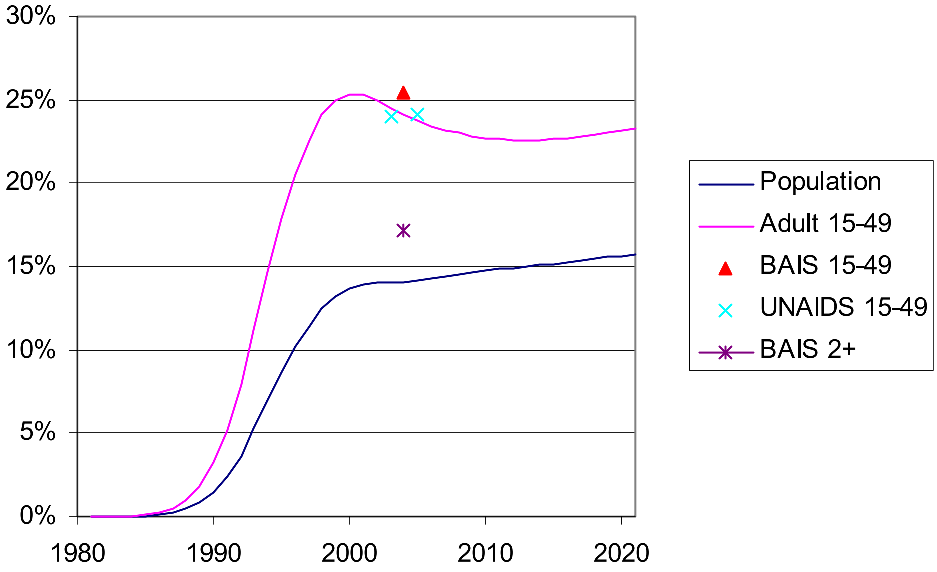



Figure 7.6 shows the prevalence of the population as a whole as well as of adults 15-49. Also included on that figure are estimates published by BAIS II and the UNAIDS.

* The number enrolled in school implied by the model was estimated by applying the percentage enrolled of children in each age group for ages 6 to 18 as reported in the census. This produced an estimate that was less than 6% greater than the number of school enrolments reported (CSO 2004). Repeating this exercise with the percentage enrolment by age reported in the BAIS II survey produced almost exactly the same number as the recorded enrolment. Thus, even though undoubtedly the gross enrolment totals will include some learners outside the 6 to 18 age range, these comparisons allowing for the degree of uncertainty in the percentage enrolment data, are very supportive of the model estimates.

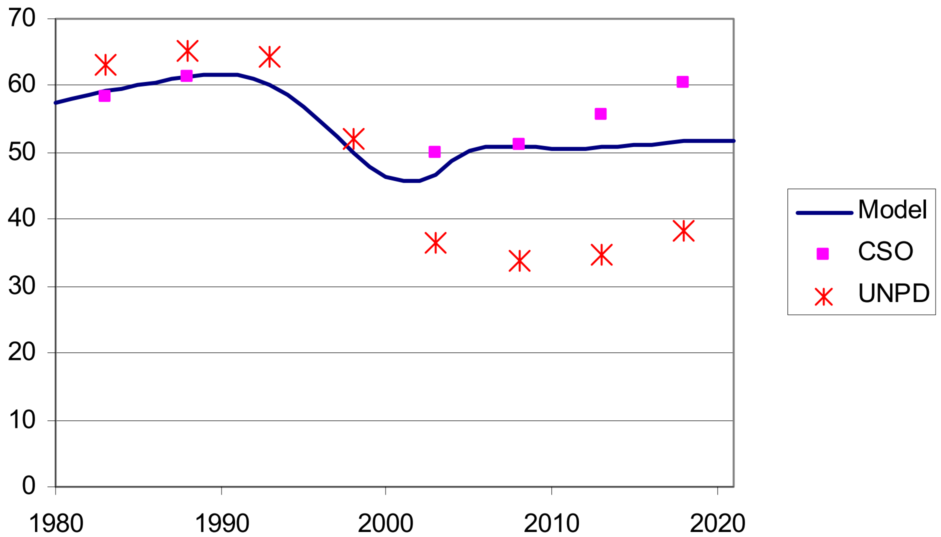
**Figure 7.6 Prevalence compared to that of BAIS (ages 2+ and 15-49) and UNAIDS (15-49)**




By and large the estimates are quite consistent, particularly so if one bears in mind that the prevalence of those under age two not covered in the BAIS II survey is somewhat lower than the population prevalence.

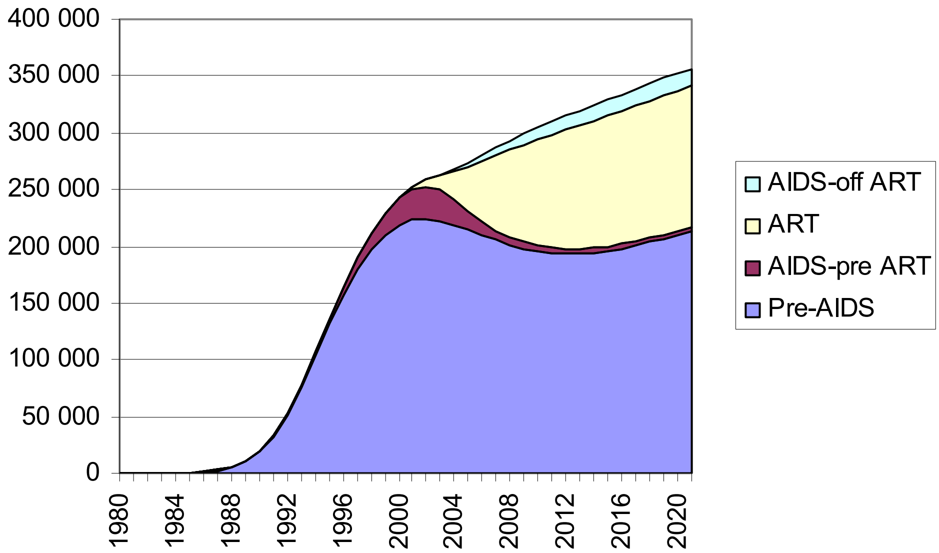
As far as life expectancy is concerned (Figure 7.7) the estimates from the model are very similar to those underlying the CSO's and UN Population Division's projections until the late 1990s, and to the CSO's until the current time, but then deviate significantly. Clearly the UN Population Division's projections are too pessimistic.

**Figure 7.7 Life expectancy compared to projections by the CSO and UN Population Division**



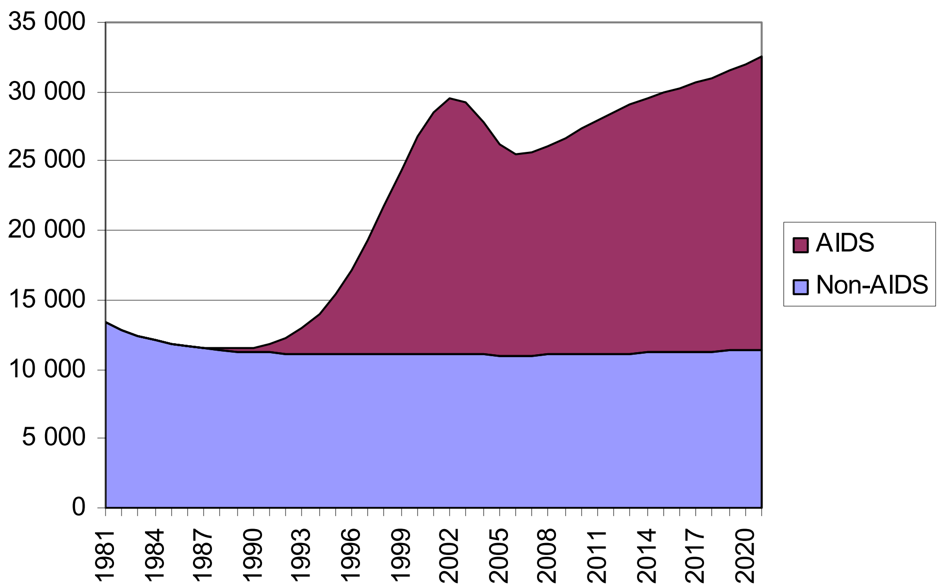

Due to the extensive provision of antiretroviral therapy the number of infected in Botswana is expected to continue increasing over the projection period. Figure 7.8 shows the total number of people infected divided into those in the pre-AIDS stages, those with AIDS who are yet to receive ART, those on ART and those who have discontinued ART.

**Figure 7.8 Numbers infected, with AIDS and not on treatment and on treatment**



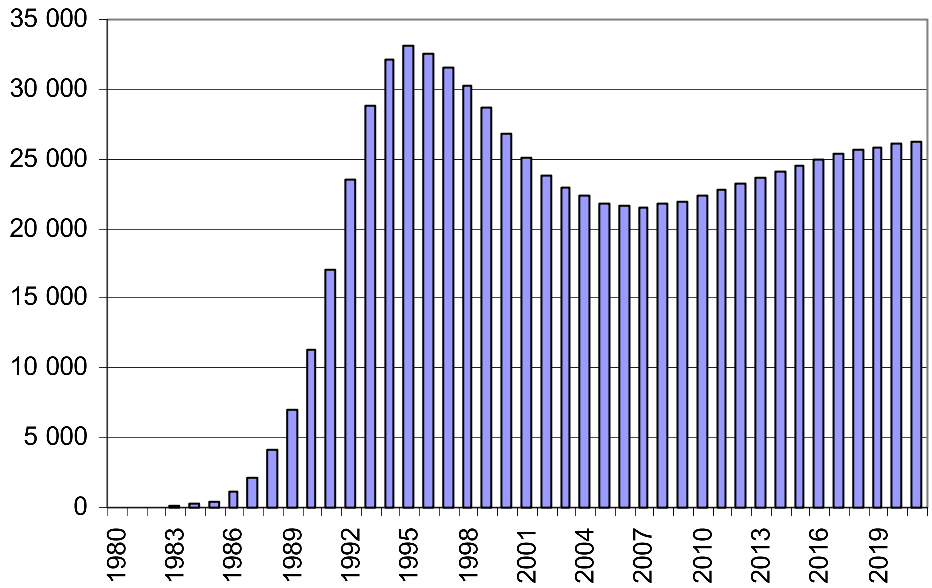

Interestingly although ART has significantly reduced the number of deaths in the past few years, according to the projections (Figure 7.9) from the model the number of deaths due to AIDS is expected start rising again soon, as those on ART succumb to the disease, as the combined impact of those on ART starting to die and a growing population.

**Figure 7.9 Numbers of deaths by age**




Similarly the model suggests that without significant change in behaviour towards less risky sex the number of new infections, having peaked in the mid-1990s may well start to rise again (Figure 7.10) as the population rises. Nevertheless, new infections never achieve the peak that occurred in 1994

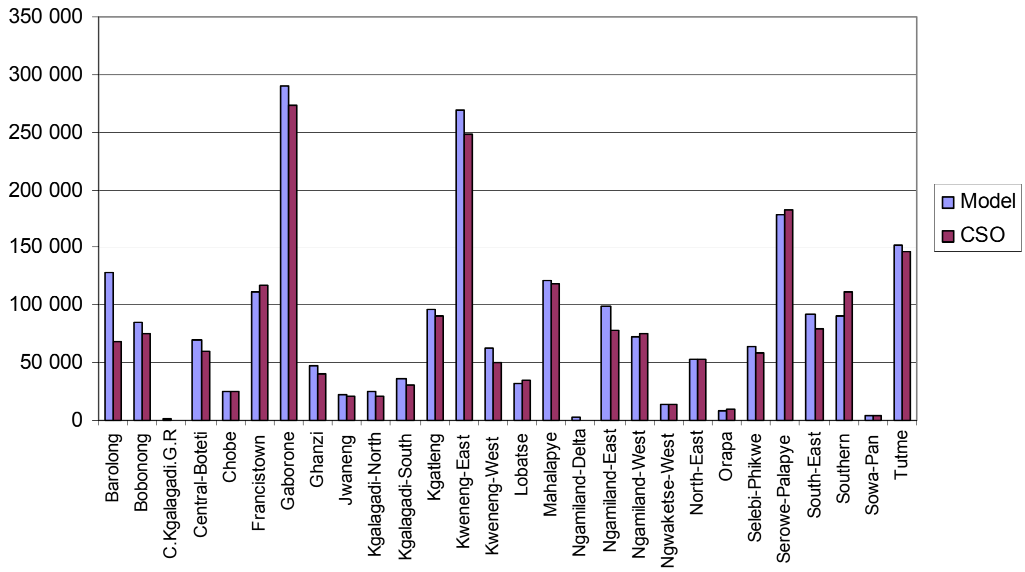
**Figure 7.10 Estimated numbers of new infections, by year**




## 7.4 Sub-districts

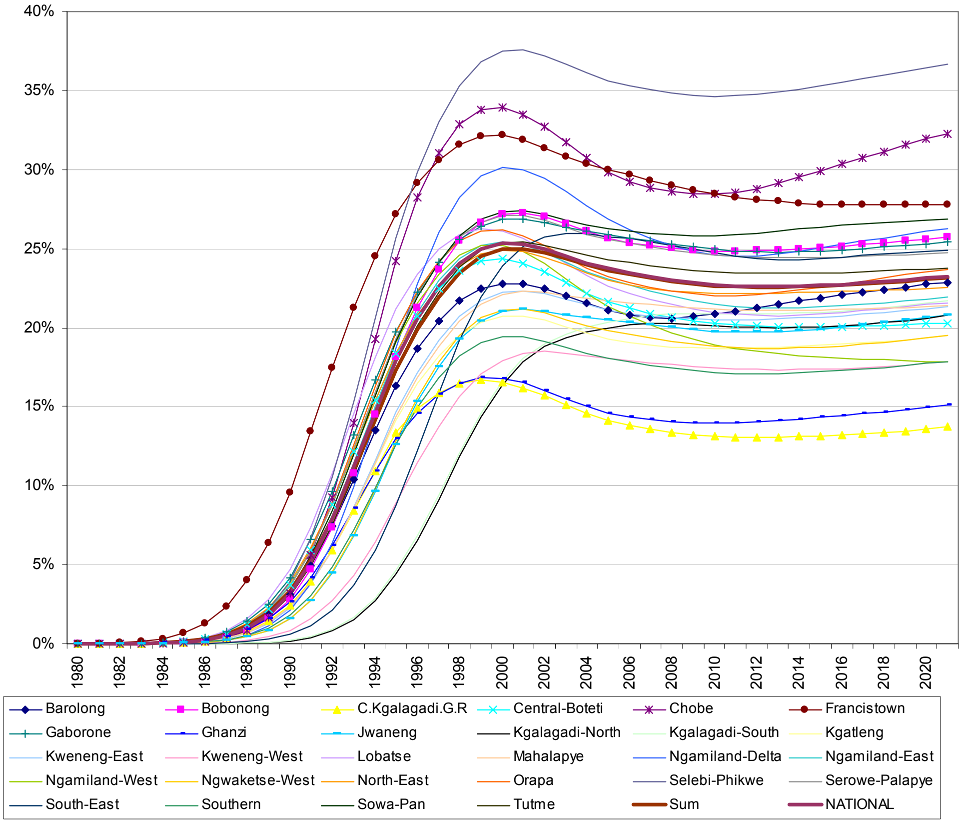
Figure 7.11 compares the projected population by census sub-district with that produced by the CSO. Allowing for the difference in the overall projection shown in Figure 7.4, the numbers are very similar, with the exception of Barolong.

**Figure 7.11 Population by census sub-district in 2020**



As is mentioned in Appendix 6, Barolong grew very rapidly between 1991 and 2001 and in projecting forward we reduced the growth rate by 2.5% p.a., which seemed sufficient adjustment, but clearly there is some uncertainty about the future prospects of this sub-district.

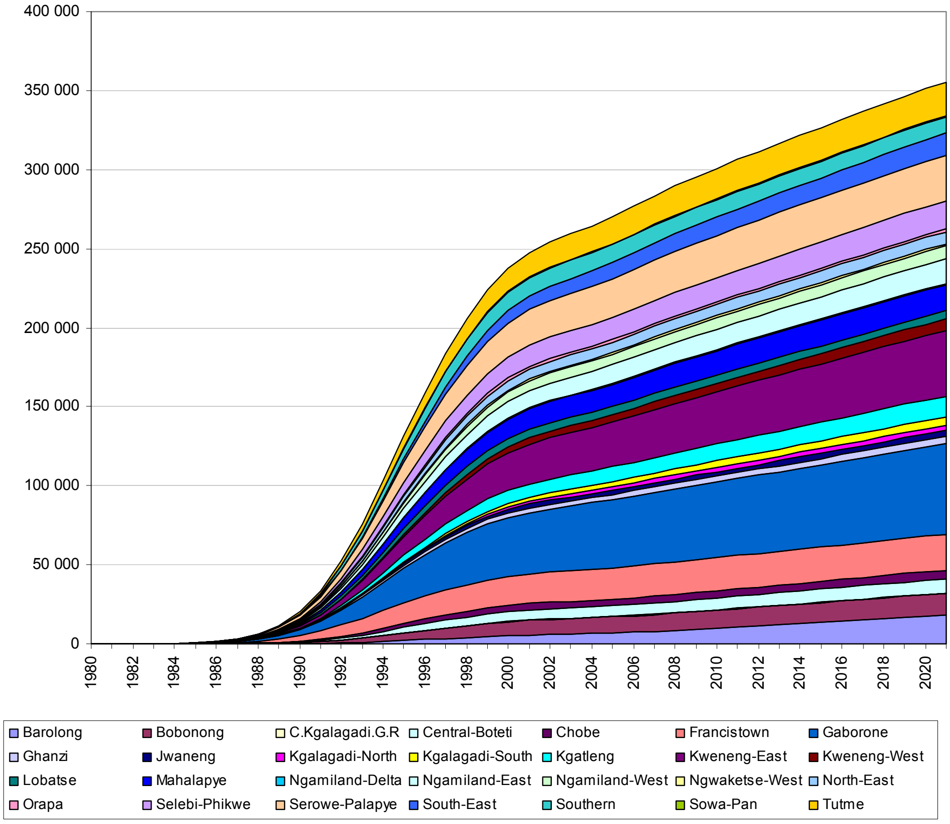
**Figure 7.12 Prevalence of adults 15-49 by census sub-district**




The timing and spread of the epidemic varies considerably between census sub-districts as can be seen from Figure 7.12 (and Table A9.3), with the epidemic in Francistown being both early and severe (along with Selebi-Phikwe and Chobe) while Kgalagadi North and South are late starters and Kgalagadi Game Reserve and Ganzi are amongst the lowest.

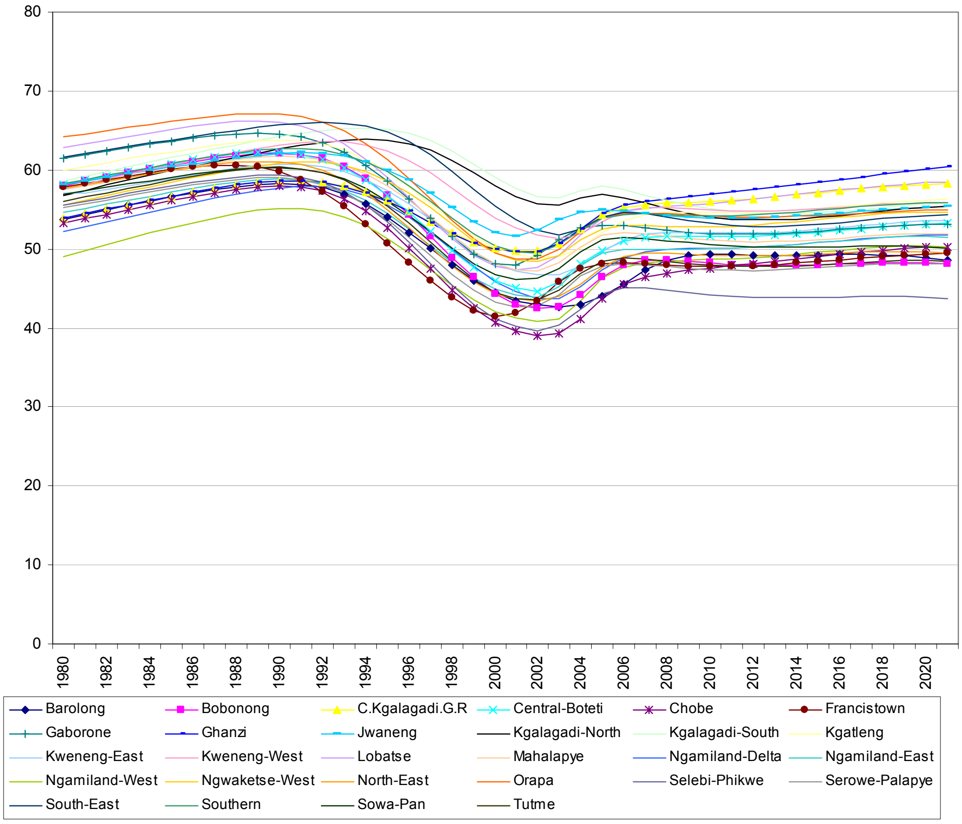
As might be expected (Figure 7.13 and Table A9.4 ) the greatest numbers infected are to be found by and large where there are the greatest concentrations of the populations, Francistown, Gaborone and Kweneng-East. Also, as noted above, the numbers of infected is expected to increase over time in most sub-districts as more people access antiretroviral therapy.

**Figure 7.13 Numbers infected by census sub-districts and year**

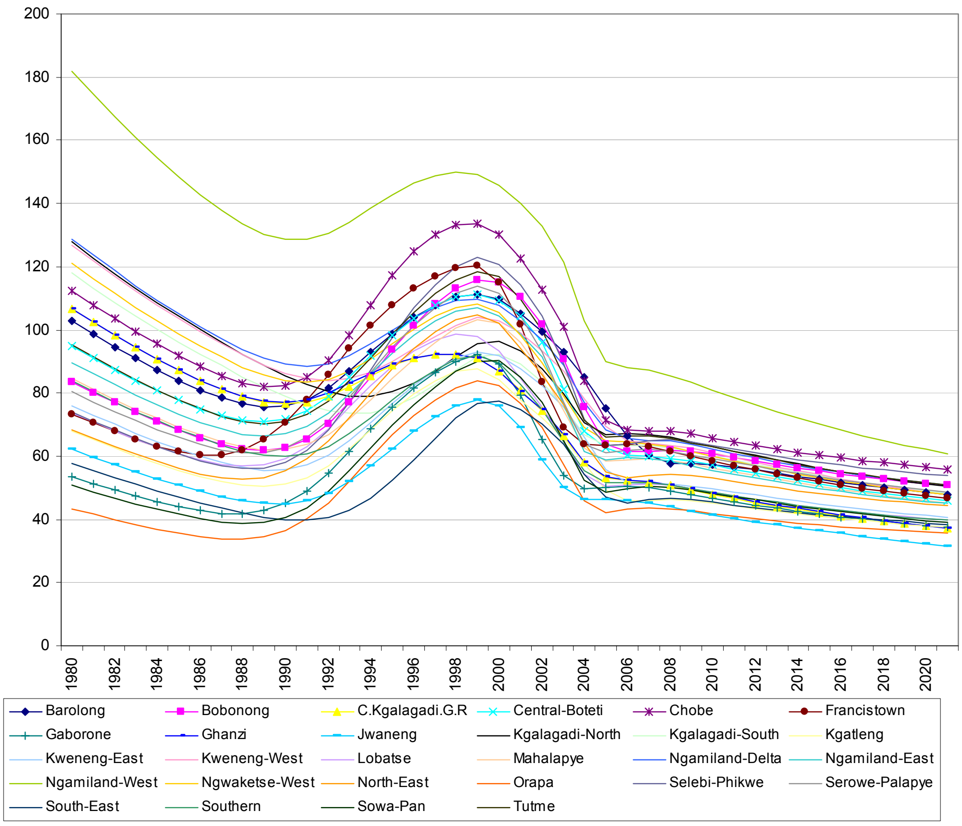



Although the different levels of infection of the various sub-districts result in different impacts on the life expectancy (Figure 7.14) and under five mortality (Figure 7.15) by sub-district, comparison of the estimates in the 1980s shows that some of the difference is due to differing non-AIDS mortality by sub-district.

## Figure 7.14 Life expectancy by census sub-district




## Figure 7.15 Under five mortality rate by census sub-district



## 7.5 Scenarios

Since there is inevitably some degree of uncertainty surrounding the assumptions underlying the model, this section presents the results from five different scenarios, in order to illustrate the sensitivity of the results to changes in some of the more contentious assumptions.

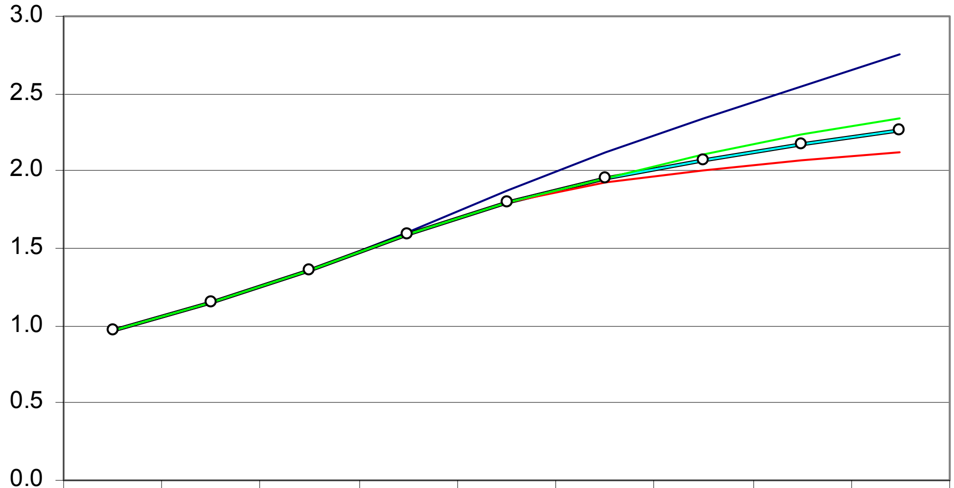
The five scenarios are

- S0 – Scenario in the absence of any HIV/AIDS infections
- S1 – The default scenario (results as presented in sections 7.2 to 7.4)
- S1.1 – Scenario 1, but assuming no ART roll-out
- S1.2 – Scenario 1, but RHT (routine HIV testing) is assumed to double the number accessing testing and counselling via VCT. This gives an indication of the sensitivity of the default scenario to assumptions with respect to the impact of RHT on behaviour.
- S1.3 – Scenario 1, but assuming a significant increase in survival on ART: assuming a halving of both the probability of discontinuing treatment and of dying while receiving ART. This increases, for adults, the median time to death from 6 to 12 years, and the mean from 8.3 years to 17 years. As with S1.2, the assumption may optimistic, but it gives a measure of the sensitivity of the results to these assumptions.

### 7.5.1 Overall population size, 1981-2021

The projected national population from 1981 to 2021 is shown in Figure 7.16. Relative to an HIV/AIDS-free population, the best estimate of the size of the Botswana population in 2021 is that it will be some 17.6 percent smaller than if the HIV/AIDS epidemic had not occurred. The population in 2021 would be possibly some 6 per cent smaller still without ART roll-out. Apart from these assumptions the other assumptions have a limited impact on the size of the total population.

**Figure 7.16 National population 1981-2021 (in millions), five scenarios**

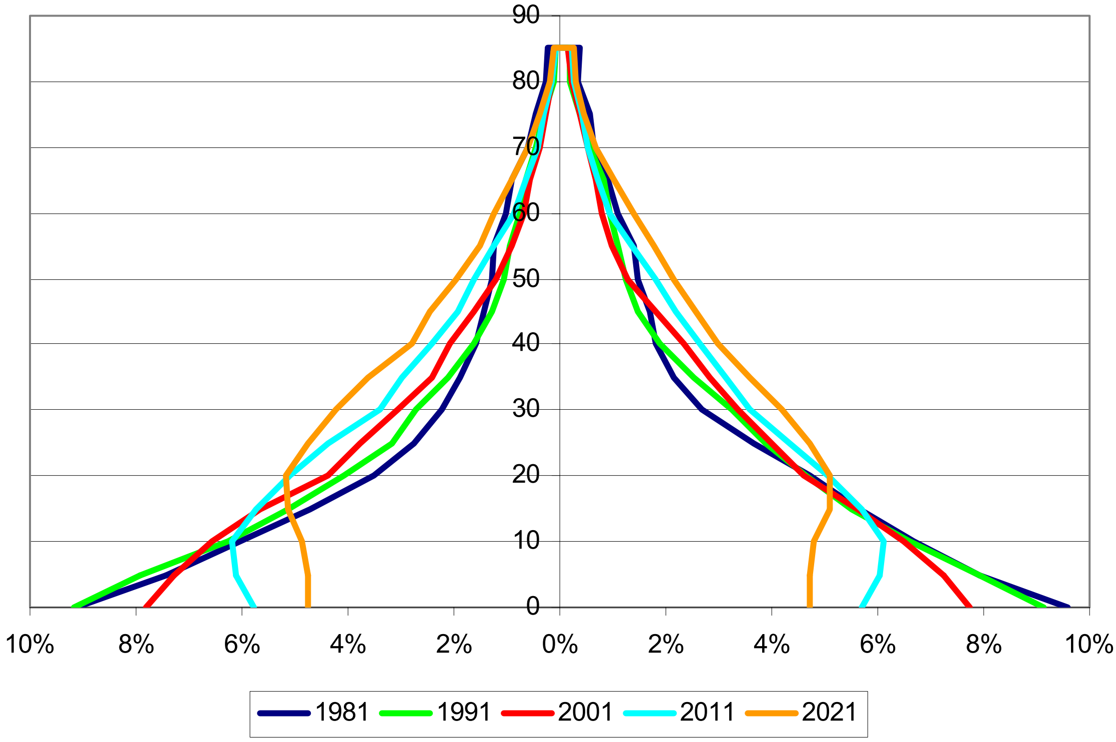



| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 0.970 | 1.147 | 1.360 | 1.606 | 1.869 | 2.121 | 2.344 | 2.551 | 2.750 |
| S1 - Default | 0.970 | 1.147 | 1.360 | 1.594 | 1.797 | 1.946 | 2.074 | 2.177 | 2.265 |
| S1.1 | 0.970 | 1.147 | 1.360 | 1.594 | 1.797 | 1.923 | 1.998 | 2.065 | 2.126 |
| S1.2 | 0.970 | 1.147 | 1.360 | 1.594 | 1.797 | 1.946 | 2.074 | 2.177 | 2.266 |
| S1.3 | 0.970 | 1.147 | 1.360 | 1.594 | 1.797 | 1.953 | 2.105 | 2.236 | 2.346 |

### 7.5.2 Age-sex distributions, 1981-2021 (no HIV/AIDS scenario)

Figure 7.17 shows the projected evolution of the age-sex distribution of the Batswana population from 1981 through to 2021 in ten year intervals. The population pyramids (with the proportion of the population in a given age group that is male on the left, and female on the right) show a typical narrowing of the base going into the future, as declining fertility rates begin to outweigh the demographic momentum associated with larger numbers of mothers.

**Figure 7.17 Age-sex distribution of the Batswana population 1981-2021, assuming no HIV/AIDS**




By 2021, the largest age-group in the population would have been that aged 20-24.

### 7.5.3 Age-sex distributions, 1981-2021 (default scenario)

**Figure 7.18 Age-sex distribution of the Batswana population 1981-2021, default scenario**

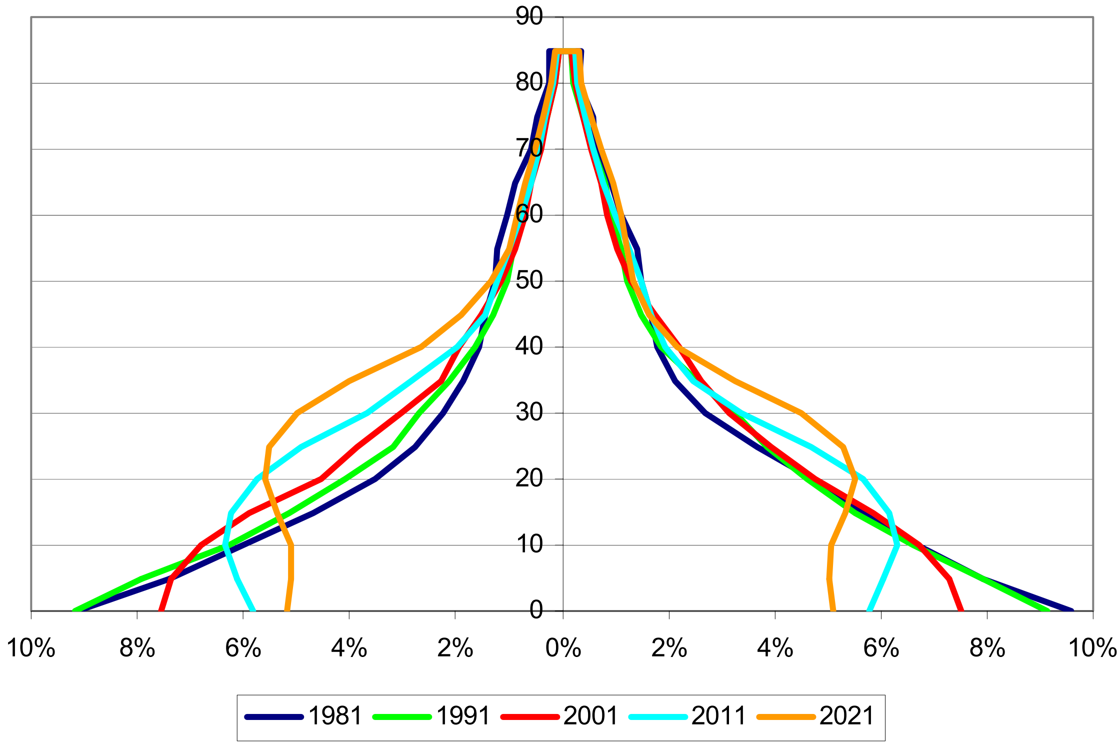
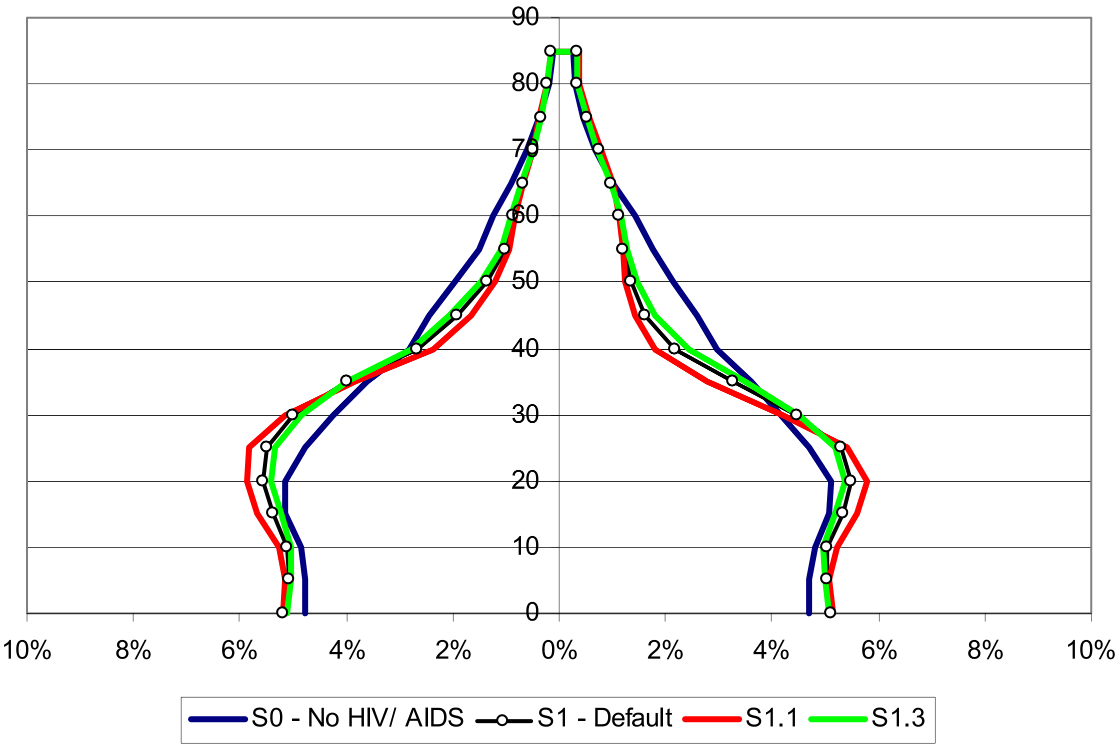


Figure 7.18 shows the projected age-sex distribution of the Batswana population from 1981 to 2021 allowing for the impact of HIV/AIDS. The overall shapes of the distributions are reasonably similar. However, a different picture is presented by Figure 7.19 which shows the comparative distributions of the Batswana population in 2021 according to the various scenarios outlined above. The results for S1.2 are omitted as they indistinguishable from those for S1, and would only clutter the figure unnecessarily.

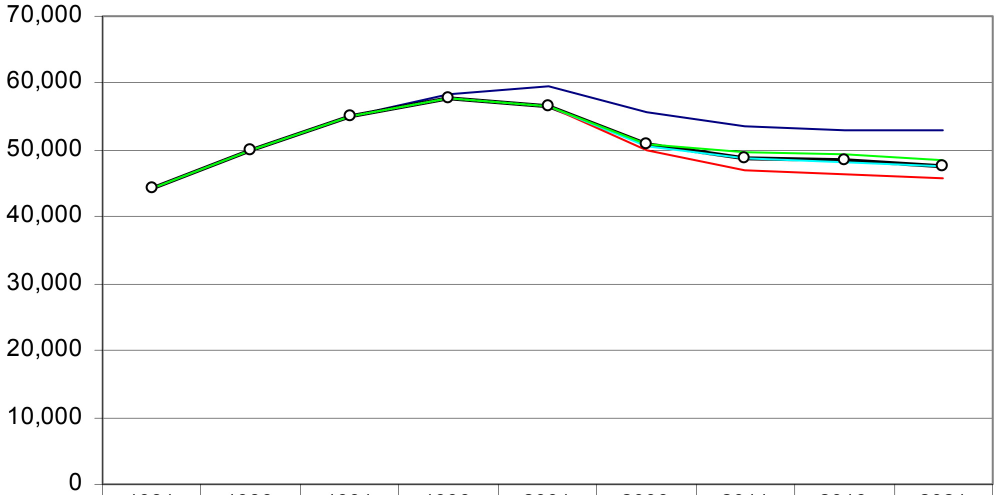
It may seem counter-intuitive, but the impact of an HIV/AIDS epidemic serves to concentrate the proportion of the population in young adult ages (ages 30 and below). This is due to the dramatic impact of HIV/AIDS on the male population aged 40 and over, and the female population aged 35 and over, where the effect of the additional HIV/AIDS-related mortality is particularly evident.

**Figure 7.19 Age-sex distribution of the Batswana population in 2021, various scenarios**



### 7.5.4 Number of births, 1981-2021

**Figure 7.20 Number of births in the Batswana population 1981-2021, various scenarios**

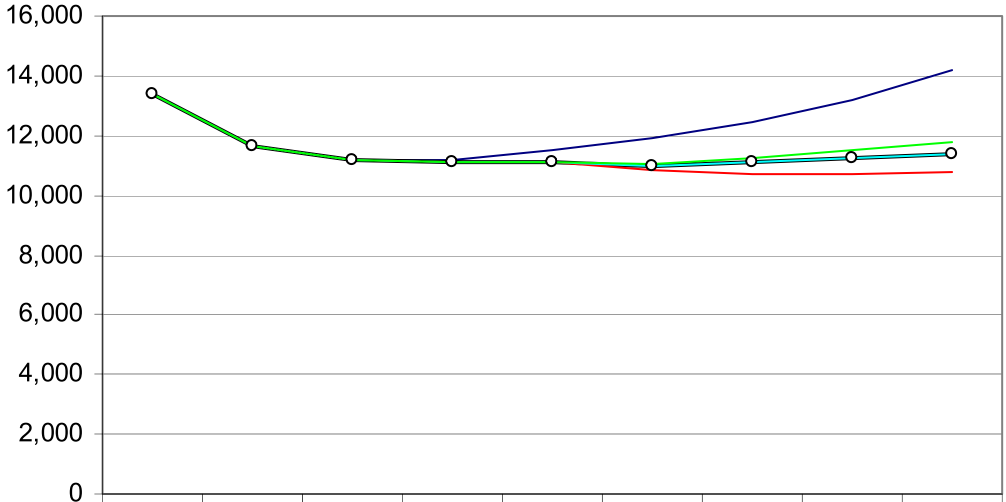



| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 44 221 | 49 821 | 55 180 | 58 301 | 59 586 | 55 607 | 53 563 | 52 964 | 52 915 |
| S1 - Default | 44 221 | 49 821 | 55 154 | 57 771 | 56 550 | 50 730 | 48 838 | 48 346 | 47 700 |
| S1.1 | 44 221 | 49 821 | 55 154 | 57 771 | 56 543 | 49 979 | 47 091 | 46 426 | 45 682 |
| S1.2 | 44 221 | 49 821 | 55 154 | 57 771 | 56 550 | 50 677 | 48 741 | 48 277 | 47 680 |
| S1.3 | 44 221 | 49 821 | 55 154 | 57 771 | 56 553 | 50 974 | 49 559 | 49 258 | 48 603 |

The number of births in the Batswana population is estimated to have peaked at nearly 60 000 per annum between 1996 and 2001, and is expected to decline thereafter, under all scenarios. The numbers of births under scenario S0 are highest while those for scenario S1.1 (no ART) are the lowest and those for the other scenarios very similar. This is mainly the result of the size of the population rather than any significant impact of HIV on fertility.

### 7.5.5 Non-AIDS deaths, 1981-2021

**Figure 7.21 Number of non-AIDS deaths in the Batswana population 1981-2021, various scenarios**

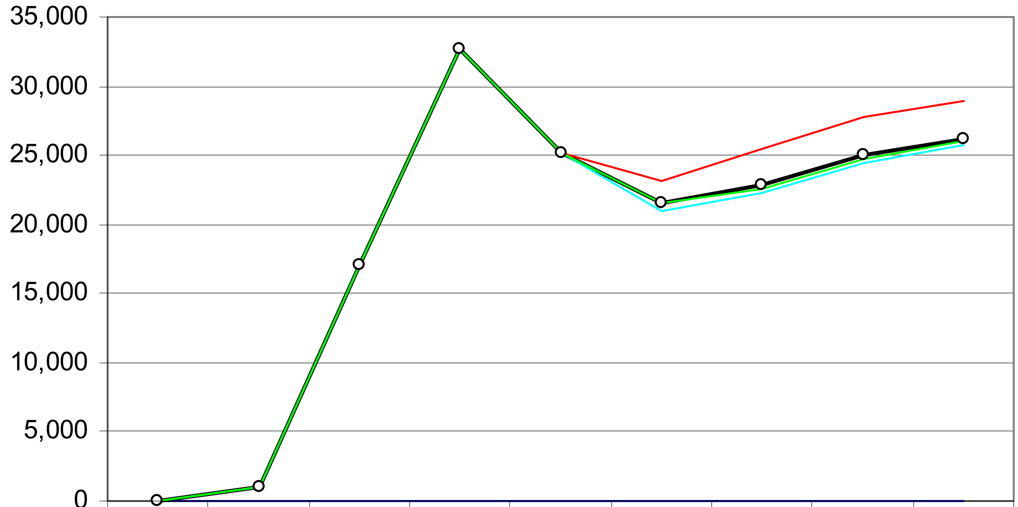



| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 13 417 | 11 663 | 11 195 | 11 183 | 11 515 | 11 885 | 12 436 | 13 195 | 14 176 |
| S1 - Default | 13 417 | 11 663 | 11 186 | 11 095 | 11 115 | 11 008 | 11 095 | 11 229 | 11 395 |
| S1.1 | 13 417 | 11 663 | 11 186 | 11 095 | 11 113 | 10 878 | 10 706 | 10 702 | 10 798 |
| S1.2 | 13 417 | 11 663 | 11 186 | 11 095 | 11 115 | 11 007 | 11 093 | 11 230 | 11 402 |
| S1.3 | 13 417 | 11 663 | 11 186 | 11 095 | 11 116 | 11 046 | 11 250 | 11 526 | 11 812 |

The number of non-AIDS deaths in the Batswana population is projected to reach a minimum of around 11 000 per annum. The numbers of deaths are a combination of the falling non-AIDS mortality rates and increasing population numbers, which ultimately leads to a reversal in the downward trend in numbers. One effect of not offering ART treatment (S1.1) can be seen in the 'crowding out' of non-AIDS deaths under this scenario.

### 7.5.6 HIV infections, 1981-2021

**Figure 7.22 Number of new HIV infections per annum in the Batswana population 1981-2021, various scenarios**



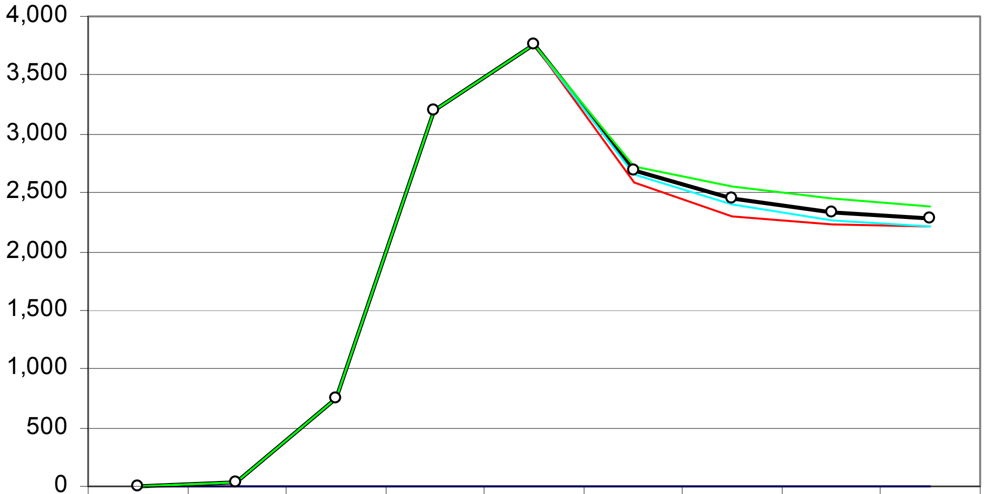

| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| S1 - Default | 17 | 1 081 | 17 081 | 32 620 | 25 158 | 21 609 | 22 805 | 24 972 | 26 218 |
| S1.1 | 17 | 1 081 | 17 081 | 32 620 | 25 197 | 23 136 | 25 396 | 27 833 | 28 922 |
| S1.2 | 17 | 1 081 | 17 081 | 32 620 | 25 130 | 20 970 | 22 243 | 24 430 | 25 700 |
| S1.3 | 17 | 1 081 | 17 081 | 32 620 | 25 157 | 21 511 | 22 622 | 24 769 | 26 004 |

Note: Data do not appear to progress smoothly due to the data representing discrete data points at five year intervals. The underlying data are smooth when examined on a single-year basis.

The number of new infections each year shows an extremely rapid rise from almost zero in 1981 to over 30 000 per annum by 1996. Under all scenarios, the number of new infections is projected to fall until 2006, and then increase gradually, as the result of increasing population numbers, again thereafter. Again, the impact of not offering ART can be seen in the higher number of new infections projected each year. This is because ART reduces viral load, and hence infectivity, and to a limited extent to assumptions about changes in behaviour of those on ART. Even under this scenario, the number of people newly infected each year does not reach the 1996 peak before 2021. The other intervention scenarios have negligible impacts on the projected number of new infections each year.

Figure 7.23 shows the number of infections arising perinatally under the different scenarios set out earlier. Unsurprisingly, since none of the scenarios target maternal transmission directly, the numbers of infants infected by their mothers varies very little from scenario to another.

**Figure 7.23 Number of new perinatal HIV infections per annum in the Batswana population 1981-2021, various scenarios**

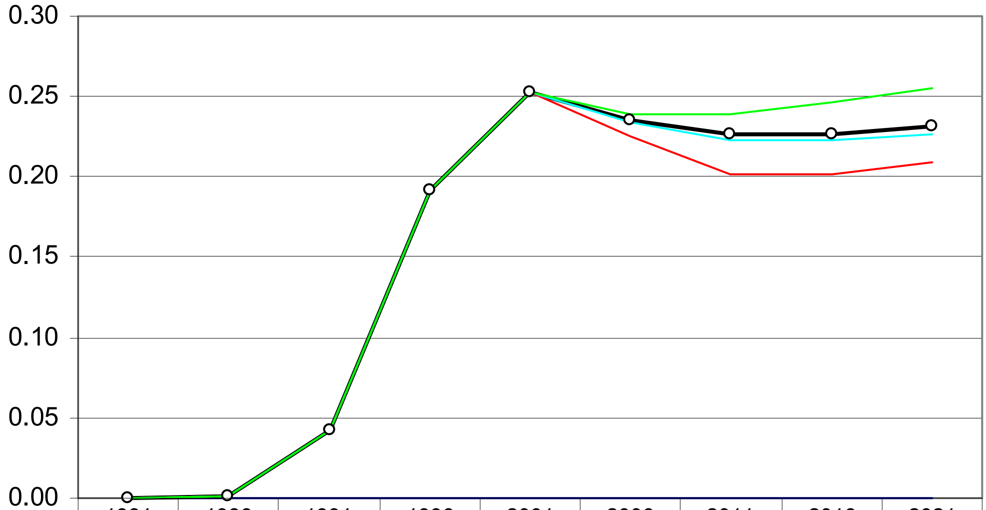



| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| S1 - Default | 0 | 30 | 746 | 3 203 | 3 769 | 2 684 | 2 454 | 2 333 | 2 277 |
| S1.1 | 0 | 30 | 746 | 3 203 | 3 767 | 2 591 | 2 294 | 2 229 | 2 209 |
| S1.2 | 0 | 30 | 746 | 3 203 | 3 769 | 2 661 | 2 402 | 2 272 | 2 215 |
| S1.3 | 0 | 30 | 746 | 3 203 | 3 769 | 2 720 | 2 556 | 2 454 | 2 388 |

Note: Data do not appear to progress smoothly due to the data representing discrete data points at five year intervals. The underlying data are smooth when examined on a single-year basis.

## 7.5.7 HIV prevalence, 1981-2021

**Figure 7.24 HIV prevalence in the Batswana population aged 15-49, 1981-2021, various scenarios**



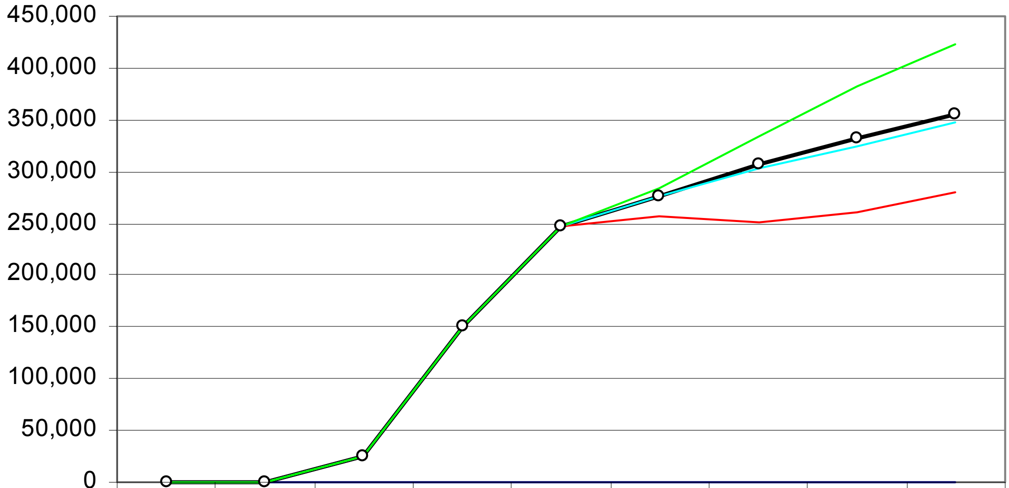

| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| S1 - Default | 0.00% | 0.17% | 4.18% | 19.23% | 25.33% | 23.59% | 22.68% | 22.70% | 23.20% |
| S1.1 | 0.00% | 0.17% | 4.18% | 19.23% | 25.32% | 22.56% | 20.21% | 20.21% | 20.93% |
| S1.2 | 0.00% | 0.17% | 4.18% | 19.23% | 25.33% | 23.44% | 22.32% | 22.23% | 22.68% |
| S1.3 | 0.00% | 0.17% | 4.18% | 19.23% | 25.33% | 23.93% | 23.90% | 24.62% | 25.50% |

Note: Data do not appear to progress smoothly due to the data representing discrete data points at five year intervals. The underlying data are smooth when examined on a single-year basis.

Figure 7.24 shows the strong differential effects of not offering ART (S1.1) and longer survival on treatment (S1.3). Adult (aged 15-49) prevalence is markedly higher under the latter scenario, due to the assumed extended survival of people infected with HIV as a result of their better adherence to treatment protocols. Again, S1.2 (RHT) has very little impact on reducing adult HIV prevalence from the 22-23 per cent projected under the default scenario from 2006-2021.

The projected number of Batswana of all ages projected to be infected with HIV is shown in Figure 7.25. The aggregate numbers are lowest under S1.1, mostly due to the shorter mean survival, post-infection, as a result of ART not being available.

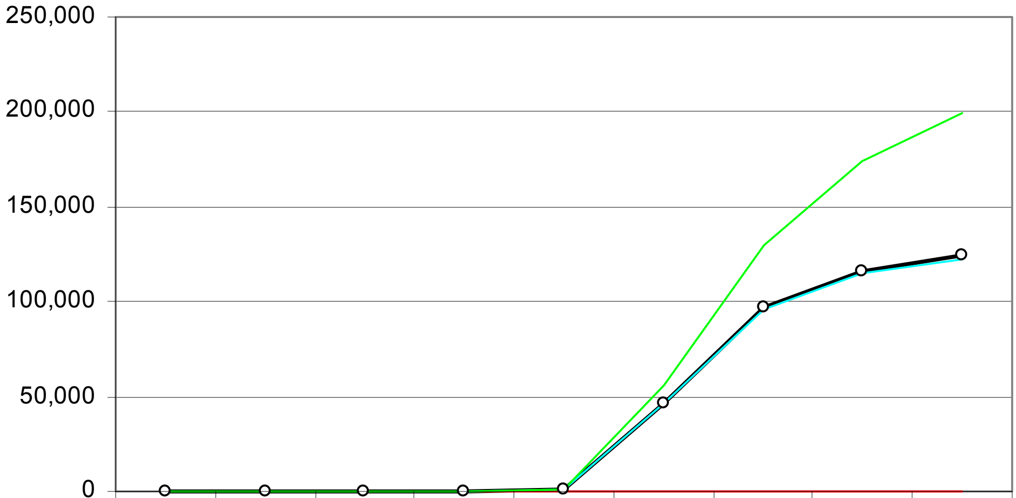
**Figure 7.25 Numbers of Batswana infected with HIV, 1981-2021, various scenarios**




| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| S1 - Default | 5 | 873 | 25 946 | 150 570 | 247 757 | 277 056 | 307 052 | 331 360 | 354 628 |
| S1.1 | 5 | 873 | 25 946 | 150 570 | 247 564 | 256 766 | 250 262 | 261 295 | 280 889 |
| S1.2 | 5 | 873 | 25 946 | 150 570 | 247 757 | 275 555 | 302 708 | 325 141 | 347 380 |
| S1.3 | 5 | 873 | 25 946 | 150 570 | 247 817 | 283 620 | 334 612 | 382 278 | 422 745 |

## 7.5.8 Numbers receiving ART, 1981-2021

**Figure 7.26 Numbers receiving ART, 1981-2021, various scenarios**

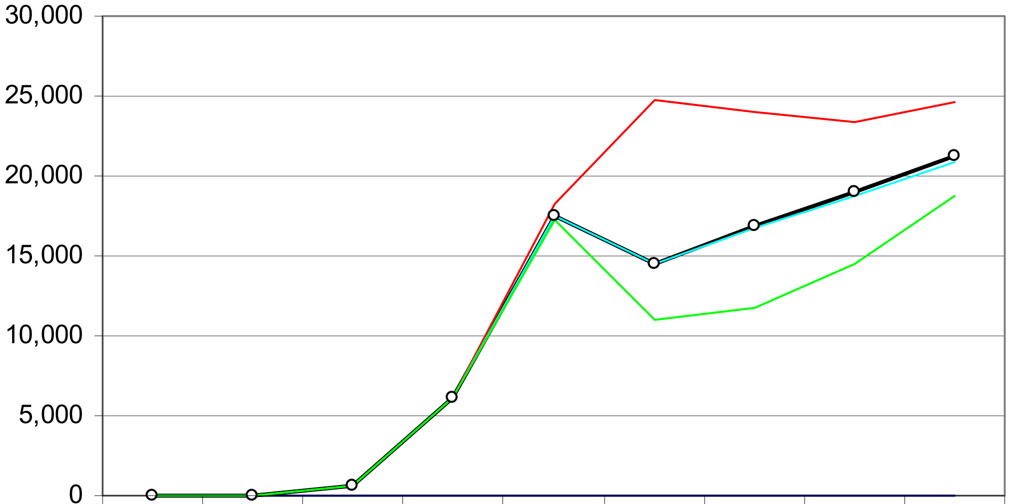



| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| S1 - Default | 0 | 0 | 0 | 0 | 900 | 46 719 | 96 571 | 116 158 | 124 078 |
| S1.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| S1.2 | 0 | 0 | 0 | 0 | 900 | 46 700 | 96 171 | 114 806 | 121 874 |
| S1.3 | 0 | 0 | 0 | 0 | 994 | 55 467 | 129 577 | 173 975 | 199 168 |

The numbers receiving ART under scenario S1.3 are almost 60 percent higher than under the default scenario, as a result of longer persistence on therapy, and extended survival. S1.2 (RHT) has a small reducing effect on the numbers of people requiring ART each year.

### 7.5.9 AIDS deaths, 1981-2021

**Figure 7.27 Estimated number of AIDS-related deaths, 1981-2021, various scenarios**



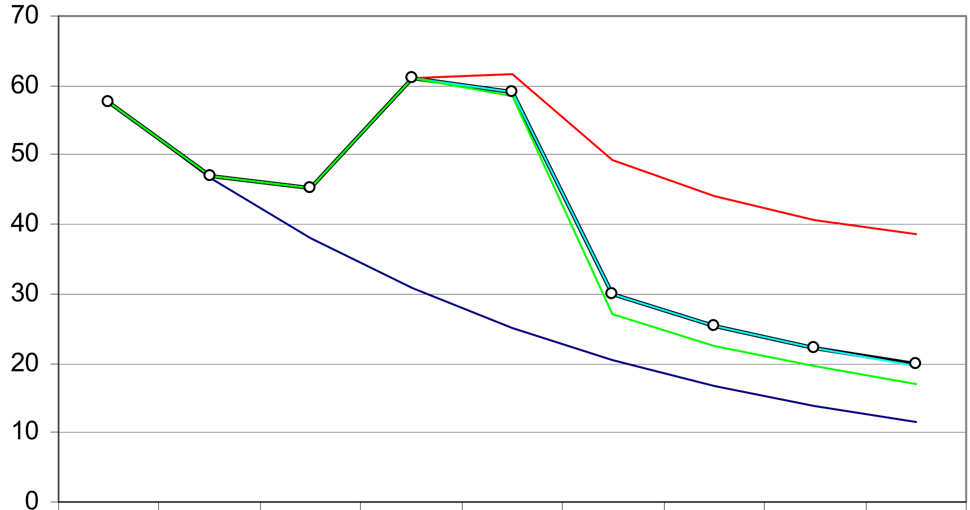

| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| S1 - Default | 0 | 18 | 648 | 6 095 | 17 455 | 14 502 | 16 890 | 19 057 | 21 217 |
| S1.1 | 0 | 18 | 648 | 6 095 | 18 312 | 24 726 | 24 023 | 23 336 | 24 609 |
| S1.2 | 0 | 18 | 648 | 6 095 | 17 455 | 14 492 | 16 793 | 18 802 | 20 839 |
| S1.3 | 0 | 18 | 648 | 6 095 | 17 219 | 11 002 | 11 739 | 14 475 | 18 743 |

Note: Data do not appear to progress smoothly due to the data representing discrete data points at five year intervals. The underlying data are smooth when examined on a single-year basis.

The number of AIDS-related deaths rises sharply to around 18 000 per annum in 2001. With no antiretroviral roll-out, the number of deaths due to AIDS would have continued to increase to around 25 000 per annum in 2006. The life-extending benefit of ART is shown in the initial reduction in numbers of deaths (to around 15 000 per annum in 2006, and 11 000 per annum under the extreme scenario indicated by S1.3), followed by a gradual rise in the number of deaths. Again S1.2 indicates a tiny effect associated with RHT.

### 7.5.10 Trends in mortality, 1981-2021: Infant and child mortality

**Figure 7.28 Projected infant mortality rate, 1981-2021, various scenarios**



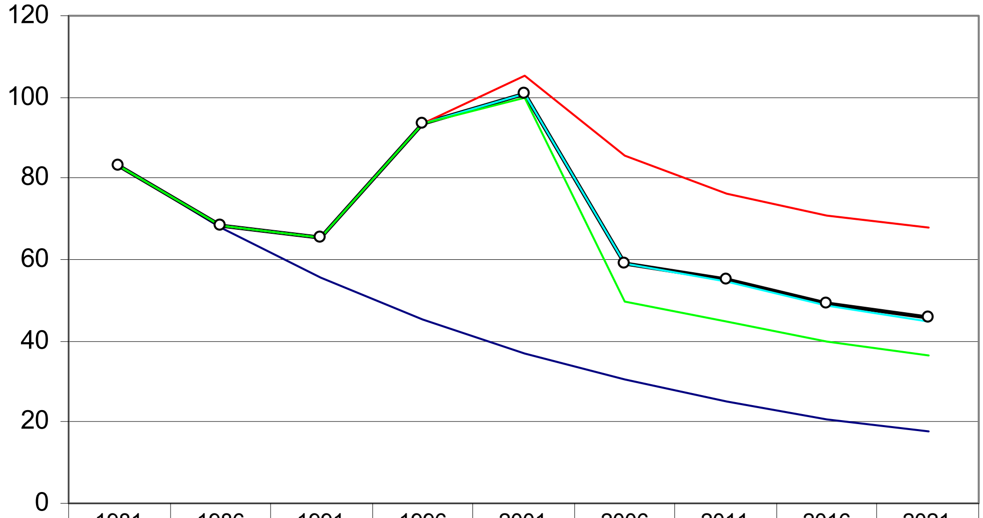
| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 57 | 47 | 38 | 31 | 25 | 20 | 17 | 14 | 12 |
| S1 - Default | 58 | 47 | 45 | 61 | 59 | 30 | 25 | 22 | 20 |
| S1.1 | 58 | 47 | 45 | 61 | 62 | 49 | 44 | 41 | 39 |
| S1.2 | 58 | 47 | 45 | 61 | 59 | 30 | 25 | 22 | 20 |
| S1.3 | 58 | 47 | 45 | 61 | 59 | 27 | 23 | 19 | 17 |

Note: Data do not appear to progress smoothly due to the data representing discrete data points at five year intervals. The underlying data are smooth when examined on a single-year basis.

The epidemic is projected to have had a significantly deleterious effect on the infant mortality rate: in 1996, the projected infant mortality rate is estimated to have been almost double that which would have been expected had there not been an AIDS epidemic. That said, the positive but limited impact of PMTCT programmes can be seen in the fall in rates for scenario S1.1 between 2000 and 2006. The significant impact of providing ART to women is shown by the even more rapid decline in rates exhibited by the other scenarios. Nevertheless, infant mortality rates are still projected, by 2021, to be some 50% higher than they would have been in the absence of the epidemic.

The impact of the epidemic on child mortality (measured by $_5q_0$, the proportion of children expected to not survive to their fifth birthday) is shown in Figure 7.29. A similar pattern to infant mortality is observed. The implication for the country's ability to meet the Millennium Development Goal of reducing the level of child mortality in 1990 by two thirds by the year 2015 should be self-evident.

**Figure 7.29 Projected child mortality rate ($_5q_0$), 1981-2021, various scenarios**




| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 83 | 68 | 55 | 45 | 37 | 30 | 25 | 21 | 18 |
| S1 - Default | 83 | 68 | 65 | 93 | 101 | 59 | 55 | 49 | 46 |
| S1.1 | 83 | 68 | 65 | 93 | 105 | 85 | 76 | 71 | 68 |
| S1.2 | 83 | 68 | 65 | 93 | 101 | 59 | 54 | 49 | 45 |
| S1.3 | 83 | 68 | 65 | 93 | 100 | 49 | 45 | 40 | 36 |

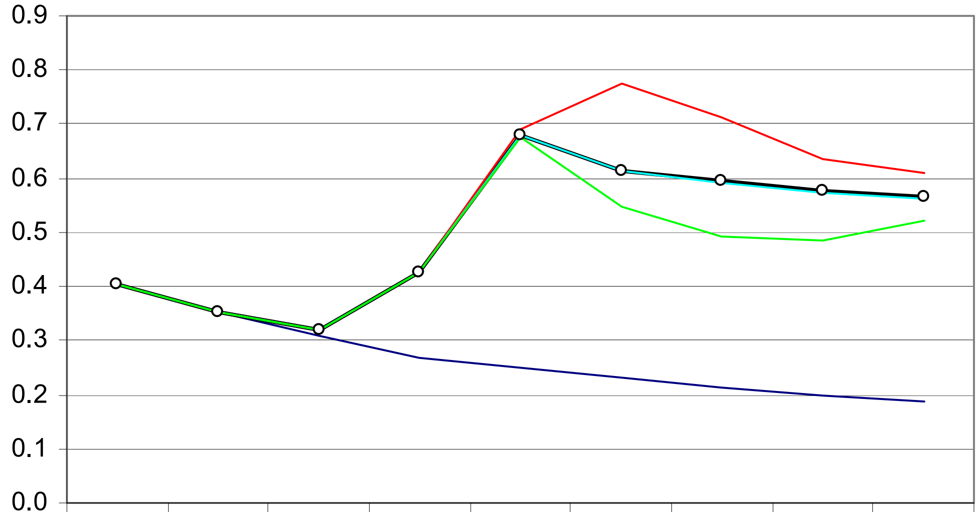
### 7.5.11 Trends in mortality, 1981-2021: Adults

A standard measure of adult mortality is $_{45}q_{15}$, the probability that a 15 year old does not survive to his or her 60th birthday. This measure of mortality is synthetic; and assumes that the person experiences mortality at future ages at the rate at which people of that age experience mortality in the year when the person is 15[*] In 1991, approximately one in three Batswana boys aged 15 would not expected to reach their 60th birthday (on this assumption). By 2001, before the impact of treatment programmes started having an effect, fewer than one third of the cohort of 15 year old boys then would have been expected to live to their 60th birthday.

Under the scenarios presented, the proportion of 15 year old boys dying before their 60th birthday would be expected to increase (a consequence of the treatment programmes assumed under the different scenarios). The biggest improvement comes, unsurprisingly, from S1.3. Nevertheless, by 2021, the probability of a 15 year old boy dying before the age of 60 would still be more than three times greater than it might have been had there not been an HIV/AIDS epidemic.

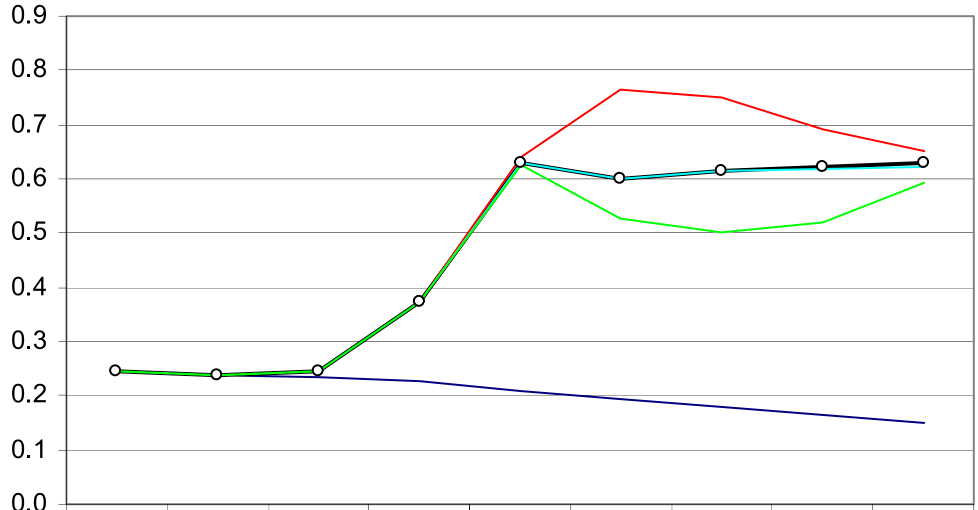
[*] Thus, for example, the measure $_{45}q_{15}$ for a boy aged 15 in 2000 would assume that, when that boy reaches age 25 (in 2010), he would experience mortality at that age (25) at the same rate as a 25 year old did in 2000.

**Figure 7.30 Projected adult male mortality ($_{45}q_{15}$), 1981-2021, various scenarios**




| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 0.4045 | 0.3534 | 0.3085 | 0.2696 | 0.2483 | 0.2303 | 0.2140 | 0.1993 | 0.1860 |
| S1 - Default | 0.4045 | 0.3536 | 0.3207 | 0.4266 | 0.6802 | 0.6142 | 0.5939 | 0.5751 | 0.5663 |
| S1.1 | 0.4045 | 0.3536 | 0.3207 | 0.4266 | 0.6916 | 0.7756 | 0.7136 | 0.6373 | 0.6080 |
| S1.2 | 0.4045 | 0.3536 | 0.3207 | 0.4266 | 0.6802 | 0.6141 | 0.5928 | 0.5722 | 0.5622 |
| S1.3 | 0.4045 | 0.3536 | 0.3207 | 0.4266 | 0.6768 | 0.5459 | 0.4920 | 0.4852 | 0.5207 |

**Figure 7.31 Projected adult female mortality ($_{45}q_{15}$), 1981-2021, various scenarios**




| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 0.2436 | 0.2379 | 0.2326 | 0.2276 | 0.2103 | 0.1931 | 0.1777 | 0.1636 | 0.1510 |
| S1 - Default | 0.2436 | 0.2382 | 0.2446 | 0.3726 | 0.6306 | 0.5993 | 0.6153 | 0.6219 | 0.6289 |
| S1.1 | 0.2436 | 0.2382 | 0.2446 | 0.3726 | 0.6419 | 0.7656 | 0.7500 | 0.6927 | 0.6511 |
| S1.2 | 0.2436 | 0.2382 | 0.2446 | 0.3726 | 0.6306 | 0.5992 | 0.6141 | 0.6184 | 0.6237 |
| S1.3 | 0.2436 | 0.2382 | 0.2446 | 0.3726 | 0.6271 | 0.5280 | 0.5020 | 0.5183 | 0.5912 |

A similar pattern is observed in the probability of 15 year old girls dying before the age of 60 (Figure 7.31). However, it must be noted that – because non-AIDS mortality for women is significantly lighter than for men – the proportional increase in mortality among adult women would be much higher than among men.

A more realistic measure of adult mortality is given in Figure 7.32 below. This is the cohort probability of a person attaining age 15 in a given year dying before he or she reaches age 60, 45 years further into the future. In other words this is, according to the model, the expected probability of a 15 year-old in a particular year dying before he or she reaches 60.

**Figure 7.32 Cohort probability of death before age 60 by year of attaining age 15, default scenario**

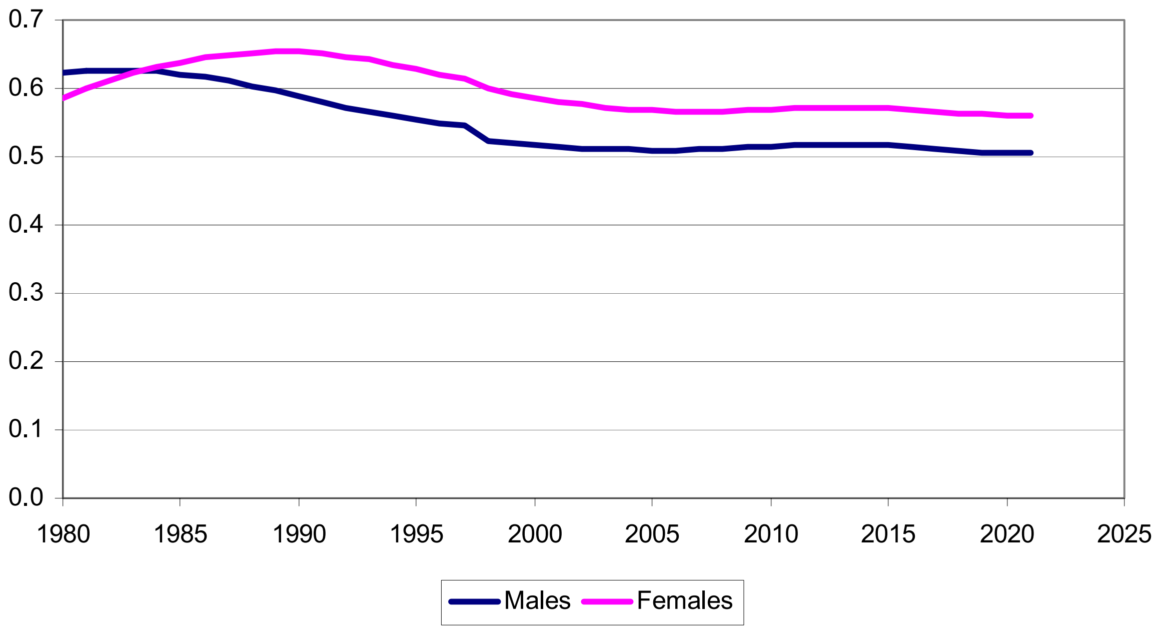
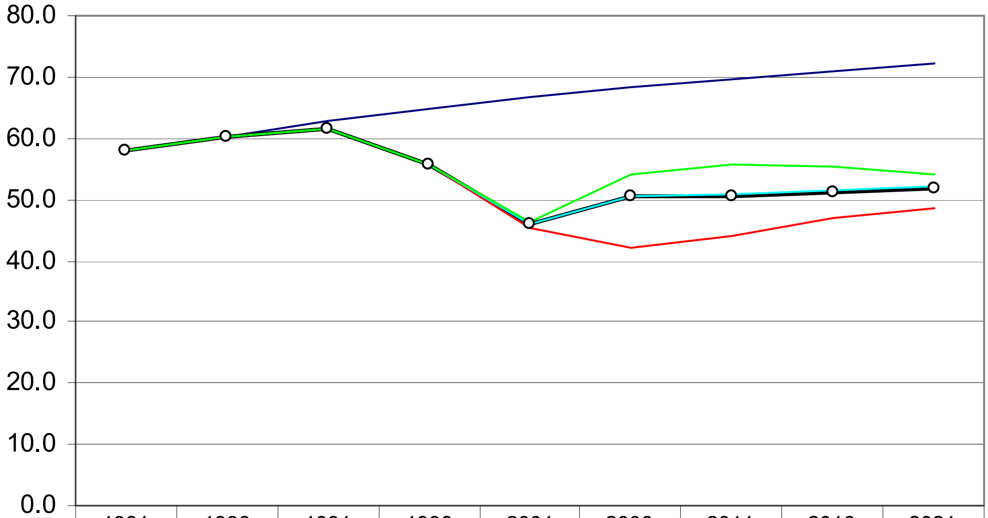



Figure 7.32 shows that for males and females attaining age 15 in years after the year 2000, the probability of dying before they reach their 60th birthday is close to 50% for males, and 57% for females.

### 7.5.12 Trends in life expectancy at birth, 1981-2021

**Figure 7.33 Life expectancy at birth ($e_0$), 1981-2021, various scenarios**

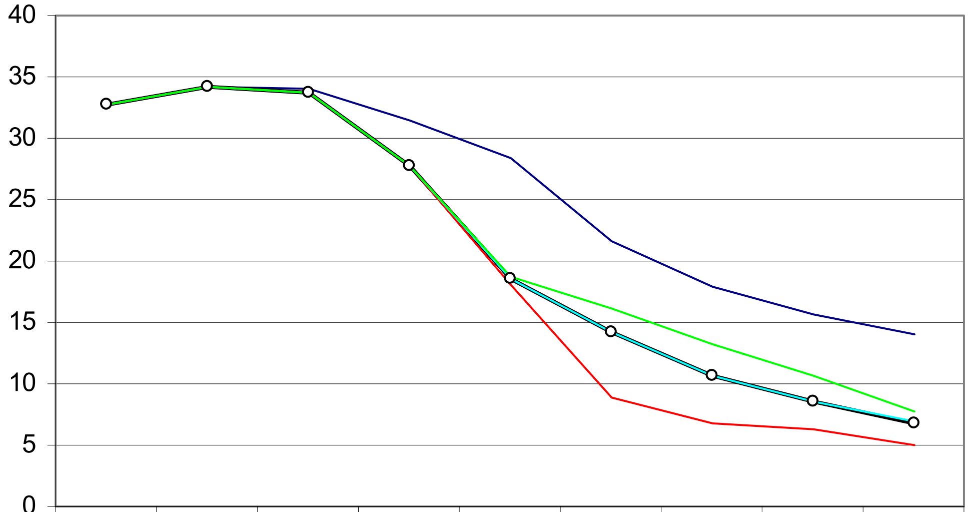


| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 57.8 | 60.4 | 62.7 | 64.8 | 66.6 | 68.2 | 69.7 | 71.0 | 72.2 |
| S1 - Default | 57.8 | 60.3 | 61.6 | 55.8 | 46.0 | 50.5 | 50.6 | 51.2 | 51.8 |
| S1.1 | 57.8 | 60.3 | 61.6 | 55.8 | 45.3 | 42.2 | 44.0 | 46.8 | 48.5 |
| S1.2 | 57.8 | 60.3 | 61.6 | 55.8 | 46.0 | 50.6 | 50.7 | 51.4 | 52.1 |
| S1.3 | 57.8 | 60.3 | 61.6 | 55.8 | 46.2 | 54.0 | 55.7 | 55.5 | 54.2 |

Figure 7.33 shows the impact of HIV on the life expectancy at birth in Botswana from 1981 to 2021. By 2021, a new born child would expect to live approximately 20 fewer years of life as a result of HIV/AIDS related mortality, and life expectancy at birth would still be some five years lower than it had been 40 years earlier, in 1981. From 2006, life expectancy at birth under the default scenario is expected to stabilise at just over 50 years, and then to increase gradually. Had ART not been made available, life expectancy at birth would have declined to 42.2 years by 2006.

### 7.5.13 Population growth rates, 1981-2021

**Figure 7.34 Population growth rates (per thousand per annum), 1981-2021, various scenarios**

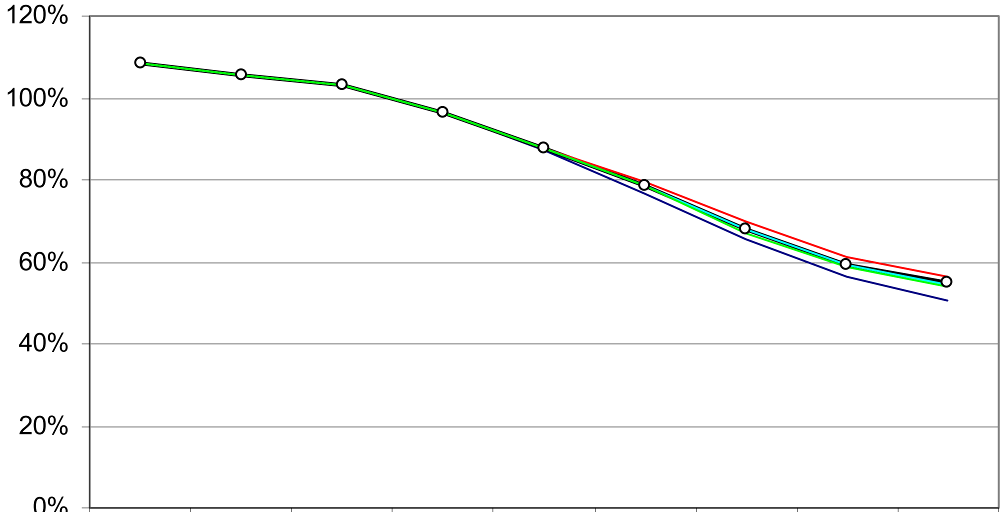



| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 33 | 34 | 34 | 31 | 28 | 22 | 18 | 16 | 14 |
| S1 - Default | 33 | 34 | 34 | 28 | 19 | 14 | 11 | 9 | 7 |
| S1.1 | 33 | 34 | 34 | 28 | 18 | 9 | 7 | 6 | 5 |
| S1.2 | 33 | 34 | 34 | 28 | 19 | 14 | 11 | 9 | 7 |
| S1.3 | 33 | 34 | 34 | 28 | 19 | 16 | 13 | 11 | 8 |

Figure 7.34 shows the projected annual population growth rates under the various scenarios. The population growth is projected to have been fastest had there been no HIV/AIDS epidemic, and slowest had there been no ART programme. By 2021, the population of Botswana is projected to be growing slowly, at around 0.5 per cent per annum. This stands is marked contrast to other projections that indicate the population growth rate in Botswana turning negative.

### 7.5.14 Dependency ratios, 1981-2021

**Figure 7.35 Dependency ratios (per cent), 1981-2021, various scenarios**




| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | 108% | 106% | 103% | 96% | 87% | 77% | 66% | 56% | 50% |
| S1 - Default | 108% | 106% | 103% | 96% | 88% | 79% | 68% | 59% | 55% |
| S1.1 | 108% | 106% | 103% | 96% | 88% | 80% | 70% | 61% | 56% |
| S1.2 | 108% | 106% | 103% | 96% | 88% | 79% | 68% | 59% | 55% |
| S1.3 | 108% | 106% | 103% | 96% | 88% | 79% | 67% | 59% | 54% |

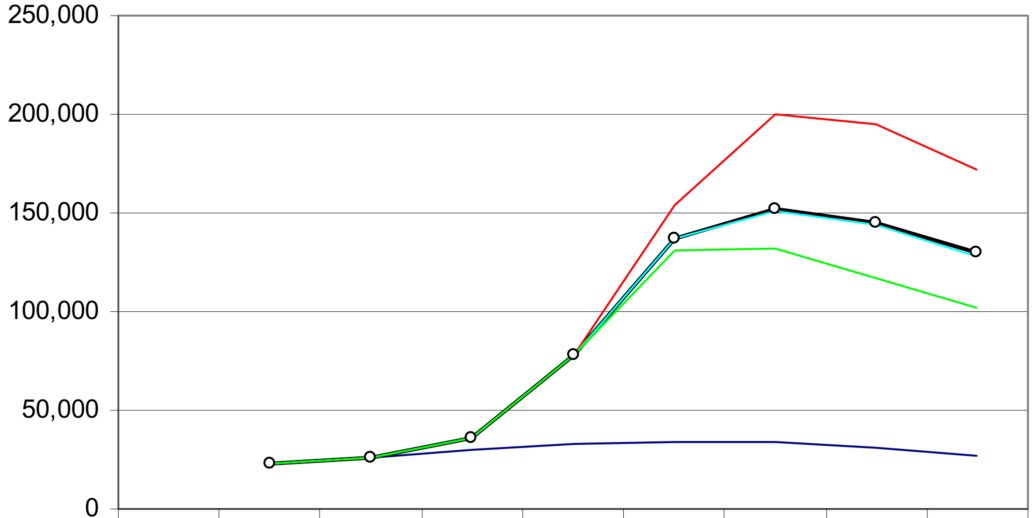
Despite the changing population structure, and the enormous impact of the epidemic on population birth and death rates, the overall effect on the dependency ratio is remarkably little.

### 7.5.15 Number of orphans, 1981-2021

The data in Figure 7.36 shows the projected number of orphans (defined as children under the age of 18 whose mother has died) under the five scenarios over the period 1981 to 2021. Under the default scenario, by 2011, the number of orphans is projected to be more than 4.5 times that which would have been observed had there not been an AIDS epidemic. If no ART roll out had occurred (which would have the effect of keeping, predominantly, mothers alive, the increase in the number of orphans would be over 30% higher, while the impact of greater survival on treatment would be to reduce the number by 10-20%.

As with other indicators shown in this section, the presumed benefits of RHT are minimal relative to the default scenario.

**Figure 7.36 Number of orphans, 1981-2021, various scenarios**




| | 1981 | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 | 2016 | 2021 |
|---|---|---|---|---|---|---|---|---|---|
| S0 - No HIV/AIDS | | 23 366 | 25 937 | 29 580 | 32 975 | 34 487 | 33 540 | 30 715 | 27 056 |
| S1 - Default | | 23 368 | 26 158 | 35 615 | 77 800 | 136 563 | 151 563 | 144 987 | 129 850 |
| S1.1 | | 23 368 | 26 158 | 35 615 | 77 925 | 154 329 | 199 659 | 195 027 | 172 270 |
| S1.2 | | 23 368 | 26 158 | 35 615 | 77 800 | 136 560 | 151 466 | 144 397 | 128 410 |
| S1.3 | | 23 368 | 26 158 | 35 615 | 77 753 | 131 345 | 132 276 | 117 083 | 101 877 |

# 8 CONCLUSIONS

Assessing the demographic impact of HIV/AIDS on the population of a country is a significant undertaking. Not only does one have to undertake independent demographic estimation to fully appreciate the demographic trends (and magnitudes) in a country in order to project trends (that could have been) in the absence of HIV/AIDS, but one needs to estimate parameters that will determine, within a model, the likely future impact of the HIV/AIDS epidemic. In the case of Botswana this involved creating models for each of the 28 census sub-districts and allowing a far as possible for district-specific differences in demography, epidemiology and interventions. Clearly such a detailed endeavour would be impossible without sufficient data. In this regard we were fortunate to secure significant amounts of both demographic and epidemiological data through the generous cooperation of the CSO, the Ministry of Health and NACA.

## 8.1 Assessment of adequacy of data and recommendations for improvements

The Terms of Reference require us specifically to comment on the adequacy of the data made available to us, as well as to reflect on possibilities for improvements. The suggestions that follow are borne out by our experience with this project, as well as on other similar projects. In most instances it is not possible to point to an existing codified standard saying that things ought to be done as we suggest; rather the points made are – for the most part – common sense.

### 8.1.1 Reports

Electronic versions of reports on demography and HIV/AIDS should be preserved and ideally made available via the web. (Initially, one could start with a simple format – everything in a general 'library' – then develop the links and sites around the links)

Good practice in producing reports.

- Include demographic data, in particular that used to produce fertility and mortality estimates, but also the census population and net immigration by sex and age.
- Include estimates from previous report for comparative purposes, not to mention eliminating a disturbing habit of 'rewriting history' without explanation.
- Ensure that sufficient explanation of method and data are presented to enable others to be able to replicate the estimates.
- Subject the report to peer-review
- Ensure that full copies of questionnaires are appended to the report: where metadata go missing (see below), a copy of the questionnaire may be invaluable to understanding the data.

### 8.1.2 Data

- Efforts needs to be concentrated on archiving data which include ensuring that there is a back-up to overcome system 'crashes' and that the platform (media and software) must be changed to keep up to date with technology. We were informed that most early (pre-2001) data collected by the CSO was no longer available in electronic format due to a server crash in 2001.
- Greater care should be taken in ensuring that there is a copy of the master data in a secure repository; and that all data sets provided for analysis are copies of this master data. Too often, the only copy of a data set was on a staff member's hard drive, where new variables had been derived and there was no way of knowing which, if any, variables had been changed or recoded.
- Datasets are not complete unless they are accompanied by metadata (a description of all variables and coding of each variable) as well as questionnaires.
- Datasets (particularly those created repeatedly, such at the sero-surveillance) should be standardized and aggregated (which is not to say that new variables can't be added, etc, but ideally the nomenclature and ordering shouldn't be altered).
- There is a need to address the issue of making data available publicly.
  - This involves deciding on a policy, ideally giving maximum public access. Data can fairly easily be anonymized by removing a single identifying variable that is not needed by the researcher (such as the EA for many researchers, etc) or a sample of the complete data could be drawn.
  - It also involves deciding on a format and making it a requirement of any projects that produce data that it be readied for release.
  - Organisations lodging data with external repositories (for example, the Africa Census Analysis Project) should ensure that they have full and unfettered rights to access those data for any reason at any time in the future. We encountered problems in this regard insofar as data lodged with ACAP by the CSO were not made available to either us or the CSO by ACAP. All we could get were tabulations on the ACAP website.

### 8.1.3 Estimation techniques

Those preparing chapters of analytical reports should be encouraged to follow 'best practice' both in terms of techniques used and experience in use of these techniques. Where this expertise and experience are not available in Botswana then experts should be employed to work jointly with Batswana on the preparation of these chapters. This is particularly the case where there have been major changes in the society (such as an HIV/AIDS epidemic) which could fundamentally violate some of the assumptions upon which some of the techniques of estimation are based.

## 8.2 High-level conclusions

A number of major conclusions can be drawn from this exercise and these have been grouped into first those which focus on the non-HIV demographic estimates, then those that reflect the likely demographic impact of the HIV/AIDS epidemic in Botswana.

This research leads to the following conclusions with respect to estimates of Botswana's demographic past:

- Based on our interpretation – and using more sophisticated techniques than applied in the Analytical Reports - fertility has been higher than has been commonly assumed, with the TFR (total fertility rate) being around 4.3 children per woman in the year prior to the 2001 census.
- Childhood mortality is significantly higher than has been previously estimated (e.g. the under five mortality rate in the year prior to the 2001 census was around 103 per thousand as opposed to 74 per thousand reported in the 2001 census analytical report). Unfortunately the indirect method that is commonly used to derive estimates of infant and under-five mortality in the absence of complete vital registration is severely compromised in an HIV/AIDS epidemic due to the violation of the assumption that the mortality of the mother and her children is independent.
- Adult mortality is probably higher than is being measured possibly due to the disintegration of some households upon the death of a household member (resulting in there being no household to report on the deaths in the reference period). We estimate that the probability of a fifteen year old not surviving to age sixty (if they suffered the period mortality rates) was 64% in the year prior to the 2001 census.
- As a result of the second and third point life expectancy in Botswana is lower than has been estimated from census data, namely around 46.5 years at the time of the 2001 census.
- Owing to the higher fertility, despite the higher mortality, projections from the 1981 census population suggest that the 1991 and particularly the 2001 census undercounted the number of children. We estimate the population in 2001 to have been about 1.815 million. As a consequence of these estimates we project the population of Botswana to be higher than others have done to date. We have confidence in this projection since the numbers of children produced by these higher fertility rates appear to be consistent with the school enrolment data.

The major conclusions about the demographic impact of HIV/AIDS are as follows:

- Prevalence in Botswana is lower than was being assumed prior to the BAIS II household prevalence survey. Reconciliation of the prevalence estimates from the antenatal survey and the household prevalence survey suggest that in 2004 around 14% of the population was infected while 24% of adults aged 15-49 were infected.
- While HIV/AIDS has had, as would be expected, a significant effect on mortality in Botswana, interventions, particularly the provision of antiretroviral therapy and the PMTCT programme have significantly reduced the number of deaths in recent years. However, this is expected to reverse quite soon with the number of deaths again increasing year on year, but at a slower rate than previously, if the assumptions about survival under treatment in the model are born out in practice. It is thus important to set in place systems to monitor the number of deaths accurately in future.
- Because antiretroviral therapy prolongs the lives of people infected with the virus the number of infected people in Botswana is expected to continue rising over the projection period. The numbers on treatment will also rise over the period reaching around 124 000 by 2021.

- HIV/AIDS is not expected to have a dramatic impact on fertility in Botswana although the number of births peaked in the late 1990s and is falling as a result of the deaths of adults in the reproductive ages.
- Under five mortality peaked around 1999 and is expected to continue falling in future, while adult mortality peaked around 2002 and is also expected to fall gradually in future.
- As a result of the peaking of the mortality rates life expectancy has bottomed (at around 45.5 years which, although lower than some estimates, is higher than many international agencies are projecting) and is now increasing.
- And also contrary to most other projections the population of Botswana is expected to continue growing, albeit at a somewhat lower rate than in the past.

It is, to all intents and purposes, impossible to précis and synthesise the material that has been presented in this report any further. The figures and output presented in the preceding section gives but a very small indication of the range of outputs that can be produced by the model that has been chosen, parameterised and calibrated against data from Botswana. The real benefit of the exercise lies in the use and application of that model by those living and working in the country to inform policy decisions in the country.

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# APPENDIX 1
# REVIEW OF THE PREVIOUS ASSESSMENT OF THE DEMOGRAPHIC IMPACT HIV/AIDS IN BOTSWANA*

## A1.1 Introduction

It is a truism that hindsight is an exact science: knowledge and information that were not available in an earlier time, but which have since come to light, inform our interpretation of the past. As a result, in evaluating earlier scientific or research endeavours, flaws and errors in data or methodology are frequently identified that now appear wrong, or naïve, but which represent the limit of knowledge at the time. Hence, evaluations of earlier projections of HIV/AIDS in Botswana may not offer much insight and care should be taken not to criticise that work simply because we have greater sophistication in our approaches now. For these reasons, the assessment of the earlier report prepared by Abt Associates (2000) for the Government of Botswana and the UNDP ('the 2000 study') is constrained to summarising the methodology and main findings of that report (A1.2); comparing the accuracy of the projections with empirical data collected after 2000 (A1.3); and an assessment of the report's shortcomings methodologically and analytically, bearing in mind the time at (and context in) which it was written (A1.4).

## A1.2 Summary of methodology and main findings

The stated objective of the 2000 study was "to provide Botswana with the best available projections of the demographic impact of HIV/AIDS on its population to 2010", and it is against this that we measure the report.

In summary, the method employed was to create a version of the Metropolitan Doyle model, calibrated to Botswana epidemiological and demographic data, and to use the results from this model to estimate the prevalence of adults (15-49), which was then used as input into Spectrum. By and large these estimates were derived to reproduce the antenatal results for each district and the population as a whole on the assumption that each sub-area followed the same prevalence curve over time, with the only difference being the lag of when the epidemic started in each year. The national figures were set to be the sum of the district projections. Although an effort was made to check output from the model against reported AIDS cases and mortality data, these were found to be somewhat unreliable and played little role in calibration of the model.

* "An Impact Assessment of HIV/AIDS on Current and Future Population Characteristics and Demographics in Botswana", report prepared by Abt Associates South Africa Inc. for the Ministry of Finance and Development Planning, UNDP and the Ministry of Health, August 2000.

The report is not clear on what, if any, other changes were made to Spectrum, and in particular the HIV/AIDS assumptions that are required by AIM. Since no information is provided to the contrary, we assume that the default (as opposed to Botswana-specific) assumptions were used for this purpose.

Various scenarios* were run, most notable of which are:

- S1 Best estimate (urban and rural prevalence the same);
- S2 Best case (rural prevalence = 80% of urban prevalence);
- S3-S10 Interventions and sensitivity to changes in underlying parameters.

The major assumptions underlying the projections contained in the report are as follows:

- District epidemics differ only in their timing (i.e. will all reach the same peak levels, but at different times);
- Population (adult) prevalence is assumed to be consistent with the antenatal prevalence and the number of reported AIDS cases;
- Median survival times are assumed to be 8.5 years for adults and "just under" 2 years for children;
- "Average" reduction in fertility due to infection with HIV is 34%;
- The MTCT rate is 30%;
- A vaccine or very effective new HIV/AIDS treatment are unlikely to be widely available before 2010;
- Migration can be ignored.

Based on the projection the report reached the following major conclusions:

- Population HIV prevalence in 1999 was estimated to be 15-17%;
- Population HIV prevalence was expected to peak at 18-21.5% by 2005;
- Prevalence among Batswana aged 15-59 in 1999 was estimated to be 28-30% (240 000) and expected to rise to 36% by 2005;
- Population incidence was projected to stay above 2% without effective prevention;
- The number of AIDS sick was estimated to be 18 000 – 19 000 (1.6-1.8% of the population) in 1999 and to rise to 39 000 – 41 500 by 2005 and to 4.5-5% of the population by 2010;
- AIDS mortality was estimated to be 1.2-1.3% of adults in 1999 and expected to rise to 3-3.5% of adults by 2010;
- A total of 327 000 to 350 000 Batswana were expected to have died of AIDS between 1991 and 2010 (20-25% of the current population);
- The total population was projected to be 1.53 million (S1) and 1.72 million (S2) by 2010, with the growth rate only remaining positive (0.2% p.a.) by 2010 under S2;
- By 2010 the number of adults aged 35-45 were expected to be 40-50% lower, and children aged 0-9 to be 32-40% lower than the numbers projected in the no-AIDS scenario;

* "S" indicates use of the Spectrum model. The Doyle equivalent were designated by "D".

- By 2005 the U5MR and IMR were expected to be 67-98 and 24-33 per 1000 **higher** respectively (depending on the scenario);
- Life expectancy was projected to be 46-52% of the non-AIDS scenario by 2010;
- The number of AIDS orphans was estimated to be 36 000-57 000 in 2000 and 159 000-214 000 in 2010;
- Rural prevalence is unusually high relative to urban areas, which was attributed to a "good communications infrastructure and highly mobile populations with oscillatory migratory patterns" and to inadequacies in the definition of what is considered to be rural and urban.

The authors make several important observations based on the conclusions drawn from their research. First, they suggest that adult prevalence (that is, HIV prevalence in the 15-49 age range) "may be considered to be optimistic", because it is around 90% of the estimates derived from antenatal clinic data. In addition, they caution that the 'best case scenario' (S2) is also too optimistic, because the fitted levels of HIV prevalence may be lower as the result of a time lag, rather than a materially different extent of the epidemic.

Second, the authors (correctly) are at pains to emphasise the uncertainty surrounding many of the parameters used in the modelling exercises.

Third, the authors intimate that they were unable to make use of the data reported in the 1991 census on household deaths; and that neither the 1996 FHS nor 1998 DHS showed clear evidence of any impact of HIV/AIDS on mortality. Their conclusions on a rising trend in mortality were, instead, based on 'anecdotal evidence' and 'problematic' health statistics and vital registration pilot data.

Finally, although they are unable to explain why the Metropolitan model produced lower estimates than the Spectrum model, they conclude that – should experience deviate markedly from the projections produced – the source of the error is more likely to be the result of incorrectly projecting the 'timing, rather than the scale of impacts'.

As an appendix, the report contains a categorically extensive, although somewhat superficial, review of seven models. As a checklist, the ratings are useful but the analysis does not allow the reader to weigh up the relative importance of one category relative to another. One does wonder to what extent the Doyle model was selected *a priori*. In passing, it is interesting to note that of the seven models evaluated three, including the model chosen to produce the projection, are no longer in use, and of those that are still in use, only the Spectrum suite and the ASSA model are widely used to model the heterosexual epidemic in Southern Africa.

The report contains a number of recommendations. It is not the purpose of the review requested in the Terms of Reference to consider the reasonableness of their recommendations or whether or not they have been acted upon.

### A1.3 Comparison of predictions with observations

Unfortunately there are not many observations against which the estimates from the previous projections can be checked directly, and even where such estimates do exist they often need to be corrected for errors and biases. However, the comparisons discussed below do allow one draw some conclusions about the reasonableness of the estimates produced by the previous study.

*Population prevalence 2004*: Estimates from the report ranged from 18.1% (S2) to 21.2% (D1) depending on scenario/model, while the estimate from the BAIS II (National AIDS Coordinating Agency (NACA), CSO and Other Development Partners 2005) was 17.1% for those over 1.5 years and only 14.1% once corrected for bias and age distribution (as part of the exercise for the current report).

*Prevalence of those aged 15-59 in 2004*: Estimate from the report ranged from 31.2% (S2) to 35.6% (S1) depending on scenario/model, while the estimate from the BAIS II was only 25% which when corrected for bias and age distribution of the sample (as part of the exercise for the current report) reduces to 23.3%.

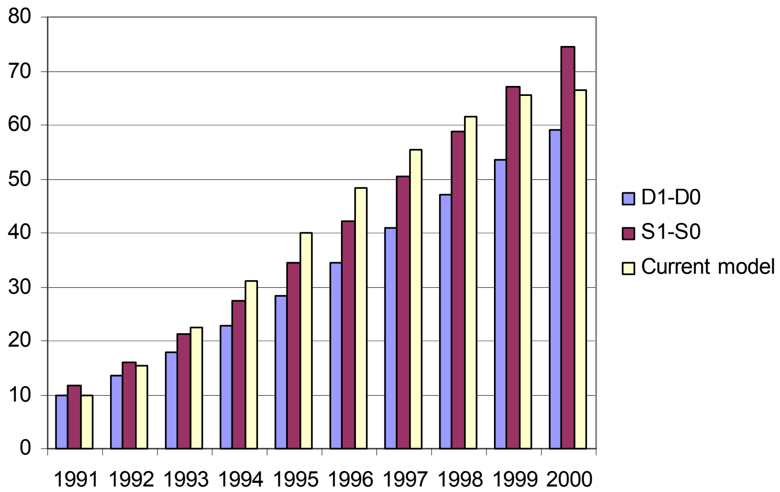
*Deaths 2001*: Estimates of the number of deaths in the year 2001 from the report range from 33 343 (S2) to 34 584 (S1) depending on scenario/model, while the number of deaths reported by households in the 2001 census was only 20 823 (Central Statistics Office (CSO) 2004a). Even if one corrects for under-reporting of deaths the number of deaths (as estimated for the current report) is barely more than 28 500.

*Total population in 1991 and 2001*: The projections derived from a base population set to be equal in size to that counted in the 1991 census (namely 1 326 796). As mentioned below the authors ignored the possibility of undercounting and smoothed the distribution of the numbers by age, treating undercounting simply as age misstatement. However, comparison of the 1991 census with the that in 2001 show clearly that the children, at least, were undercounted in 1991. Estimates for the current report suggest that the total population in 1991 should probably have been around 1 382 000.

Estimates for 2001 from the report range from 1 590 793 (D1) to 1 720 390 (S0) depending on scenario/model, while the census count was 1 680 863, and allowing for the undercount of children (as estimated as part of the current report) this total increases to 1 814 700. Thus, in terms of age, the numbers in the report underestimate the population (even the census population at some ages), particularly ages under 20.

*Under-five mortality*: Figure A.1 compares the absolute difference between the under-five mortality rate allowing for the impact of HIV and that not accounting for it. All three sets of estimates show a significant increase in under-five mortality reaching (and possibly peaking at) 60-75 per mille, however, despite assuming far lower prevalence rates than used for the previous models the current model produces higher estimates than the previous models in most years. The significant difference between the Doyle and Spectrum estimates is probably due the assumption in the Doyle model that non-AIDS mortality remains constant over time.

**Figure A.1 Excess under-five mortality (per 1000) due to AIDS for various scenarios/models**




### A1.4 Shortcomings of the report

The major problems with the research can be grouped under several headings.

#### A1.4.1 Methodological

First, the report made no attempt to compare the projections produced with those produced by other teams of researchers, or using other models. The inability to explain why the Doyle model projected a less severe impact than indicated by the Spectrum model is one such example.

Second, the consultants, not being demographers, did not undertake any independent demographic assessment of the data used for calibration. In particular they failed to compare the mortality rates implied by the projection against empirical estimates of mortality rates. Had they done so they might have been forced to constrain the projected peak in prevalence rates somewhat. In the same vein, other flaws in the work arising from an inability to work with demographic data include:

- The consultant's failure to adjust the 1991 census data appropriately for the undercount, particularly of children;
- The use of (apparently) unweighted data from the 1998 DHS;

- Reliance on the 1996 FHS and 1998 DHS surveys. Careful interrogation of these data sources would have indicated that these surveys were not good descriptions of the population of Botswana, and that – in any event – the sample sizes are too small to have offered reliable statistics;
- The failure to make use of the 1991 census data on household deaths points more to the project team's weakness in the field of demography, rather than the inadequacies of the data per se;
- The assertion that numbers of AIDS-related deaths is less important than data on HIV prevalence. As an epidemic matures (and that in Botswana in 2000 was showing signs of maturity), calibration of a model against <u>both</u> prevalence and mortality becomes necessary;
- The assumption that the prevalence of the districts followed the same trend over time, simply adjusted forward or backward in time was really made for modelling convenience rather than that the data (limited though it was) supported such an assumption;
- The smoothing of the population curves in Figure 2 (page 24) is problematic. The projected population (as well as the smoothed one) is <u>less</u> than that actually observed in the 1991 census for ages 8-20 (approximately). It is hard to see how the census would have overcounted the population in this age group. Instead, the conclusion must be that the smoothing process did not check that its results were reasonable;
- Related to this, in the same figure, the choice of fertility rates between 1980 and 1991 is shown to be problematic by the evident discontinuity in the modelled population at age 10. The population curve, by age in 1991, would appear to comprise two convex curves, one for age 0-10, the other for ages 10 and above, with a discontinuity at age 10. This is almost certainly indicative that the fertility estimates used in the model in the years 1980-1990 (and, similarly, beyond) are too low, a point borne out in Appendix 4, which shows that the estimates of fertility from the 1991 census are significantly understated. This is the opposite conclusion reached by the consultants, who – in Table 5 (page 25) – force the 1980 estimate of fertility downwards;
- A more careful approach to evaluating the demographic data on fertility (summarised in Table 2 on page 16 of the report) would have alerted the consultants to potential data problems.

### A1.4.2 <u>Assumptions used in the modelling process</u>

A number of the assumptions used in the modelling process are questionable. These include

- The assumption of a median survival time from infection to AIDS of 8.5 years for adults. This contrasts with the projections done in 1997 which they cite (but do not reference but presumably produced by the CSO) which apparently employed a median term "to AIDS" of 10 years followed by "100% mortality" two years thereafter; and 2 years for children (children infected after three months from birth tend to survive much longer than this);
- The assumption of an average reduction in fertility of 34% at all ages. Other sources of bias in the antenatal figures are, however, ignored;
- They assumed a 30% probability of transmission from mother to child. This figure is possibly on the low side and given the assumption of survival of infected children ignores the findings, which were apparent at that time (Spira, Lepage, Msellati *et al.* 1999), that children infected after birth survive much longer.

- Many results (e.g. the mortality rates in their Table 3) are cited with references which are not listed in the report, and thus difficult to assess further.
- The authors cite evidence from a KAP study that condom use during last sexual encounter was 85%. This is inherently implausible, and is strongly indicative of desired response bias.
- The consultants assume that non-AIDS mortality is constant in the future. While this may be a reasonable assumption in the case of adults, it is unlikely to be the case for child mortality, which has typically shown evidence of a continued decline in Southern Africa.

### A1.5 Conclusions

While the work undoubtedly represents a useful attempt to project the impact of HIV/AIDS on the population of Botswana at the time, and there is certainly merit in first modelling the impact using a sophisticated model and then using the results to produce a simpler model, the work suffers from three major problems.

First, although estimates were produced for each of the districts these were constrained to ensure that the prevalence in all districts would (eventually) peak at the same level. By doing this, not only were the epidemics in the districts misrepresented but the combined effect ignores any heterogeneity between epidemics in the various districts other than timing (which might not be a factor in a small, highly mobile population like Botswana, certainly not as the epidemic matures).

Second, the model was not calibrated to mortality data (with the exception of highlighting suggestive trends). Thus too much reliance was placed on one source of data, the antenatal clinic survey, to determine the level of the epidemic, and hindsight suggests that this is a fairly biased source from which to estimate prevalence.

Third, the estimates were undermined by a lack of focus on the demographic assumptions underlying the projection. The projections are based on too small a base population misshaped by smoothing, migration was ignored, fertility under-estimated and non-AIDS under-five mortality overestimated, in the Doyle models, at least. As a result the projections underestimate the population in future, particularly at the younger ages. Despite this, the projection, certainly up to 2001, over-estimates the number of deaths, by about 5-10% if our estimates are correct.

# APPENDIX 2
# REVIEW OF MODELS

## A2.1 Introduction

The purpose of this section is to evaluate the models available for projecting the demographic impact of HIV/AIDS in Botswana. The list of models considered, although extensive, is not intended to be exhaustive. In the main, we have concentrated on models that have been applied to Botswana in the past or that are publicly available.

There are two fundamental criteria to be applied in evaluating each of the models, namely, the ability of the model to meet the needs of the user and the availability of data required as input in the model. These two factors are discussed in further detail below. Section A2.2 reviews the models. Section A2.3 compares the models and draws conclusions.

### A2.1.1 Needs of the user

The needs of the user are of primary importance in choosing an appropriate vehicle to model the population of Botswana. Crucially, the model must be sufficient and robust in meeting the users' specified needs. Models that cannot meet this criterion are of very limited use.

The needs of the user include the model's ability to perform sub-national, in addition to national, projections; the model's ability to evaluate the implications of interventions on the future course of the epidemic (again, both nationally and sub-nationally); and the capacity of the model to provide sufficient detail to permit the assessment of the impact of the epidemic on the economy and health management systems.

### A2.1.2 Availability of data

The amount of data required, and their availability are central in determining the success or accuracy of the model. Erroneous assumptions made, perhaps, due to there being insufficient data, may have a significant impact on the overall results. Furthermore, models that do not utilize all available data but which use generic assumptions as inputs may not provide accurate results, with even less accuracy at a sub-national level. However, there is a trade-off in so far as the more input assumptions that are required (which, typically, would result in better projections), the less likely it is that valid estimates of all those input assumptions will be available. Hence, over-parameterised models are as problematic as models that are over-simplified.

### A2.2 Review of models

This section includes the various models reviewed. As all models are not identical, the models are evaluated according to a pre-specified set of attributes in order to assess their strengths, weaknesses and adequacy. For each model that is evaluated, a brief description of the model is provided, followed by a discussion of the approach adopted to modelling the transmission of HIV, sexual behaviour and post-infection survival. Finally, some general comments on the model's ease of use are offered.

#### A2.2.1 ASSA2003

**Brief description of ASSA2003**

The model's primary purpose is to estimate the demographic impact of HIV/AIDS on a country's population. The model was developed by the AIDS committee of the Actuarial Society of South Africa (ASSA). The first version was released in 1996. The model has evolved in parallel in two different ways. First, the model is continually modified to incorporate the latest research on the dynamics of HIV epidemics in predominantly heterosexual populations. Second, the model is calibrated continuously against relevant data for the population being modelled. The numbering of the model version is somewhat misleading, referring to the latest year of South African antenatal clinic data against which the model has been calibrated. However, for reasons of version control, substantive changes to the engine of the model are only release to the public at the same time as a recalibration is made available.

The ASSA model is a spreadsheet-based model programmed in VBA for Excel. It projects age-by-age and year-by-year changes in an initial population profile on the basis of a number of demographic, epidemiological and behavioural assumptions. The population is divided, by sex, into three distinct age groupings: young (up to age 13), adult (14-59) and old (60 and above). Different demographic, behavioural and epidemiological assumptions are made for each group, which is then projected on a single-age, single-year basis. The adult group (assumed to be the sexually active population) is further subdivided into four risk groups differentiated by level of exposure to the risk of contracting HIV through heterosexual activity. These risk groups are:

**PRO** Individuals whose level of sexual activity is such that it is similar to that of commercial sex workers and the level of condom usage and infection with STDs is similar to that of the STD group.

**STD** Individuals whose level of sexual activity is such that their HIV prevalence is similar to someone regularly infected with STDs.

**RSK** Individuals with a lower level of sexual activity, but who are still at risk from HIV in that they have, on average, one new partner per annum and sometimes engage in unprotected sex.

**NOT** Individuals who are not at risk of HIV infection.

The assumptions are determined, where possible, on the basis of empirical evidence relevant to the population being modelled. Where this is not possible, either educated guesses are made or the assumptions are determined through calibration, the processes whereby the results generated by the model are adjusted to be consistent with observed data such as the antenatal prevalence figures.

The model projects on a year-by-year basis, with each year's projections reflecting changes between 1 July of one calendar year and 30 June of the following calendar year.

The model allows for the effect of interventions (prevention and treatment programmes) on sexual risk behaviours, probabilities of HIV transmission and HIV survival. Currently, five interventions are modelled:

- improved treatment for sexually transmitted diseases (STDs);
- information and education campaigns (IEC) and social marketing;
- voluntary counselling and testing (VCT);
- prevention of mother-to-child transmission (PMTCT); and
- anti-retroviral treatment (ART).

Data from census, demographic surveys, household surveys, antenatal clinics and vital registration systems are required in order to apply and calibrate this model to a particular country. Furthermore, data from behavioural surveys and data on the interventions listed above are required for setting assumptions or parameters in the model.

The model allows for differential male and female migration by age explicitly. In addition, allowance is made for the impact of HIV, by duration of the infection and age, on fertility. Bias in antenatal data is also adjusted for.

The model produces various detailed output. This includes, but is not limited to, the numbers of people in each sex/risk group/HIV classification and in total; the number of people sick with AIDS; the number of deaths due to AIDS and other causes, separately; HIV prevalence rates among the different risk groups; HIV incidence rates; mortality statistics including life expectancy; numbers of people accessing prevention and treatment programmes; and the number of adults and children in each different stages of HIV disease. Each of these outputs can be generated for individual ages and years. The model is thus highly flexible, and it can be further easily customized to produce any additional outputs that can be derived from the model's underlying data. For a more detailed description of the model see the manual (Dorrington, Johnson and Budlender (2005)) and Johnson and Dorrington (2006).

**Modelling the transmission of HIV**

Initially, infection is introduced into the PRO risk group via the number of male and female infected 'imports'. These imports are not added to the population, but rather used to create HIV prevalence of partners in the initial years and hence start the epidemic. Thereafter, the epidemic spreads through the population at risk by assumed infection of non-infected individuals within and between groups. The rate of spread of the infection is controlled by assumptions about the amount of sexual activity and the probability of infection. Furthermore, an individual's infectiousness is assumed to vary according to the duration of the infection and whether or not the individual is on ART.

**Modelling sexual behaviour**

Sexual behaviour, and thus the probability of infection, is modelled on the basis of a combination of the following components:

- the probability that a male partner is from a particular risk group;
- the probability that a female partner is from a particular risk group;
- male-to-female transmission probabilities per sexual contact for various combinations of risk group encounters;
- female-to-male transmission probabilities per sexual contact for various combinations of risk group encounters;
- the number of new partners per year and the number of contacts per new partner per year;
- condom usage for each risk group by age;
- the effectiveness of condoms; and
- relative frequencies of sex, frequency of condom use and levels of HIV infectiousness, in different stages of HIV disease.

**Modelling HIV survival**

The median term to death of HIV-infected individuals, HIV survival, is assumed to differ according to the age at which an individual is infected. Those infected at younger ages (14-24) are assumed to survive for longer in an asymptomatic state than those infected between ages 25 and 34. Those infected after age 35 are assumed to have the shortest survival. Survival after infection is further split between six identified stages of the disease. The first four correspond to the WHO Clinical Staging System, namely, acute HIV infection; early disease; late disease and AIDS. The fifth represents individuals receiving Highly Active Anti-Retroviral Therapy (HAART), and the sixth represents individuals who have discontinued HAART. The time spent in each of the first four stages and the sixth is assumed to follow a Weibull distribution. In the fifth stage the probability of transition is the same for each year except the year in which treatment begins, when it is substantially higher.

**Ease of use**

The model is freely available to the public via the ASSA website. It is used widely across South Africa and has also been applied to other countries in Southern Africa. It is easy is to use. Being a spreadsheet model, it does require a basic understanding of Excel. A user manual is available to guide inexperienced users. Training and ongoing help is available through the model's custodians.

The model is, relative to other models, highly transparent. Users who are familiar with elementary mathematics, spreadsheets and computer programming can easily follow the logic of the ASSA model and understand how the assumptions or parameters interact.

Calibration should only be conducted by an experienced user. Furthermore, due to the interdependence of different parts of the model, it is sometimes not easy to predict the effects of a particular change. However, re-calibration should only seldom be necessary since, as far as possible, the parameters of the model are set by reference to empirical studies.

Re-calibration is required should the model start deviating significantly from observed data in the population being modelled.

### A2.2.2 SimulAIDS

**Brief description of SimulAIDS**

The model was developed by INSERM U88 (Paris) in collaboration with the School of Public Health in Kinshasa (Zaire) and the Tulane University (USA). It is a simulation model of the transmission dynamics of HIV infection and of other sexually transmitted diseases in populations where HIV infection is predominately heterosexually transmitted. The model has been described in detail in a number of papers (Auvert, Buanamico, Lagarde et al. 2000; Bernstein, Sokal, Seitz et al. 1998; Robinson, Mulder, Auvert et al. 1995, 1997).

SimulAIDS is stochastic and micro simulation in nature, and characteristics are therefore determined separately for each individual in the population. More than 100 input parameters are required, which can be divided into seven groups, namely, demographic; general sexual behaviour; infection through social contact; infection through non-sterile injection; infection through blood transfusions; mother-to-child transmission: and prognosis for infected individuals. Furthermore, being stochastic, the model must be run hundreds if not thousands of times in order to determine the distribution of possible results. The time-step between each iteration in a particular projection is usually 1 to 5 days.

The demographic parameters are assumed to be independent of the level of HIV infection. In addition, mortality rates and fertility rates are assumed to be constant over time. Thus the model is not suited for long-term projections.

Intervention strategies can be included in the model to determine their effectiveness in fighting the spread of the epidemic. Examples of interventions which have been modelled are improvements in STD treatment and health seeking behaviour for STDs, reduction in the rate at which 'one-off' partnerships occur and increases in condom use with 'one-off' partners (Bernstein, Sokal, Seitz *et al.* 1998). The model has also been used to assess the potential impact of HIV vaccines (Stover, Garnett, Seitz *et al.* 2002).

As the model requires more than 100 input parameters, it is likely that there will not be sufficient data for Botswana to satisfy all these parameters. Furthermore, the model does not allow for migration or the impact of HIV on fertility.

**Modelling the transmission of HIV**

The model allows for changes in HIV infectiousness over the course of HIV infection, though different papers describing the model have offered different assumptions regarding these changes in infectiousness. In all cases, HIV infectiousness is assumed to be very high in the first few weeks of infection, then drops to low levels for most of the duration of infection, before increasing again a few months before progression to AIDS (in most cases, sexual activity is assumed to cease after this). The model also allows for the simulation of other STDs and for their effect on susceptibility to HIV infection. In two papers, STDs are distinguished according to whether they cause ulcerative or non-ulcerative symptoms (Robinson, Mulder, Auvert *et al.* 1995, 1997), and the ulcerative STDs are assumed to have the greatest effect on HIV transmission.

**Modelling sexual behaviour**

Three types of partnerships are modelled in SimulAIDS: long-term (marital) partnerships, short-term partnerships and 'one-off' relationships (involving a single sex act). Individuals are assumed to be less likely to engage in 'one-off' and short-term relationships once they are married, but after controlling for marital status, rates of partnership formation are assumed not to be related to age.

Condom usage is also incorporated in the model, but at a constant rate.

**Modelling HIV survival**

In applying the SimulAIDS model to the HIV/AIDS epidemic in Uganda, Robinson *et al* (1997) assume a fairly short average time from HIV infection to death (4.5 years). Auvert *et al* (2000) assume a longer mean HIV survival time (7.5 years). In both cases, the HIV survival time is split into four stages: the acute stage (the few weeks in early infection when the individual is highly infectious), the asymptomatic stage, the pre-AIDS (symptomatic) stage and the AIDS stage. The combined time spent in the asymptomatic and pre-AIDS stages is assumed to follow a uniform distribution, and the times spent in the acute stage and the AIDS stage are fixed.

**Ease of use**
SimulAIDS is freely available from INSERM U88 (Paris). It is not easy to use and requires a thorough study of the user manual in order to carry out projections. Furthermore, there is no known use of this model in Southern Africa. Ongoing help and support may not be available. In addition, additional software is required in order to display the results graphically.

Calibration is difficult as there are over 100 input parameters and should only be conducted by an experienced user. Due to the large number of parameters, stochastic HIV/AIDS models would be very difficult to apply to populations of more than 10 000 to 20 000 individuals. It is highly unlikely that SimulAIDS, or any other stochastic model, could be applied to modelling the course of HIV/AIDS in Botswana with any degree of accuracy. For this reason, other individual-based stochastic models are not considered here. These stochastic models are listed below, together with references to detailed descriptions of the models.

- The STDSIM model (Korenromp, Van Vliet, Bakker *et al.* 2000; Korenromp, Van Vliet, Grosskurth *et al.* 2000)
- The Populate model (Bracher, Santow and Cotts Watkins 2003, 2004)
- Sam Clark's model (Clark 2001)

### A2.2.3 iwgAIDS

**Brief description of iwgAIDS**
The model was designed by Stanley, Seitz and Way of the Interagency Working Group. Relatively few published papers have described the model (Bernstein, Sokal, Seitz *et al.* 1998), and it has not been developed or updated since its initial creation.

iwgAIDS is a highly sophisticated deterministic model. The impact of the epidemic can be analyzed along several demographic and epidemiological dimensions. As suggested in section A2.1.2, however, the number of parameters required by a model increases dramatically with increasing sophistication. This model is no exception, and the data requirements in order to successfully fit this model are substantial.

Interventions can be allowed for directly and their impact on the epidemic assessed. Examples of interventions which have been modelled using iwgAIDS are improvements in the effectiveness of STD treatment (Bernstein, Sokal, Seitz *et al.* 1998) and HIV vaccines (Stover, Garnett, Seitz *et al.* 2002).

**Modelling the transmission of HIV**

As in the SimulAIDS model, the iwgAIDS model assumes that HIV infectiousness is increased significantly during the first four weeks of infection and then reduces substantially during asymptomatic HIV infection. At the onset of the first AIDS-defining illnesses, HIV infectiousness is assumed to increase again, and (unlike the SimulAIDS model) sexual activity is assumed to continue despite AIDS symptoms. The model also allows for the simulation of other STDs, which are assumed to increase susceptibility to HIV as well as HIV infectiousness (in individuals who are co-infected with HIV and other STDs).

**Modelling sexual behaviour**

Similar to the SimulAIDS model, the iwgAIDS model allows for three types of partnerships: long-term partnerships, short-term partnerships and 'one-off' partnerships. The model also allows for different types of sexual intercourse. The individual's age is assumed to affect the rate at which he/she changes partners, the frequency of sexual intercourse, the types of partnership formed and the types of sexual intercourse.

**Modelling HIV survival**

The time from HIV infection to death is split into three phases: the acute phase (lasting four weeks), the pre-AIDS phase and the AIDS phase. No further information on the modelling of survival is supplied by Bernstein *et al* (1998).

**Ease of use**

iwgAIDS is a complex model. It is freely available for public use. Technical documentation is available. However, a skilled user is required in order to use the model effectively. Furthermore, calibration is difficult.

### A2.2.4 Nico Nagelkerke's model

**Brief description of Nagelkerke's model**

This model was developed for the purpose of assessing the relative merits of different HIV prevention and treatment strategies. The model has relatively few input requirements. It is programmed in ModelMaker and has been described in detail by Nagelkerke *et al* (2001). The model is not structured by age, and as such is of very limited use from a demographic point of view. It is nevertheless included in this review as it has been applied to Botswana and is therefore of some interest.

The model is deterministic, and works by splitting the population into a number of 'compartments' (representing different levels of risk behaviours, different sexes, different HIV disease stages and different HIV strains). The demographic assumptions required are minimal and include only the initial size of the population in each compartment, at the start of the epidemic, a constant (with respect to both age and time) non-AIDS mortality rate (assumed to be 0.03 when the model was applied to Botswana), and the rate at which individuals enter the sexually active population (again assumed to be 0.03 in Botswana). Births are modelled independently of the calculation of entrants to the sexually active population, and for this purpose it is assumed that fertility rates are the same in HIV-positive and HIV-negative women. There is also no allowance for migration. This lack of demographic sophistication all but renders the model useless for demographic projection.

Examples of interventions modelled include increased condom usage in contacts between sex workers and clients, syndromic management for STDs, prevention of mother-to-child transmission and highly active antiretroviral treatment (HAART).

**Modelling the transmission of HIV**

The probability of HIV transmission is assumed not to depend on the time since HIV infection. It is, however, assumed that individuals who are receiving antiretroviral treatment and who have not developed drug resistance are not infectious. After drug resistance develops, individuals are assumed to be as infectious as they would have been if they had not started HAART, and it is assumed that they transmit drug-resistant strains rather than drug-sensitive strains. Although infectiousness after development of drug resistance is assumed to be the same as in untreated infection, allowance is made for possible reductions in risk behaviours after starting HAART, which may render individuals receiving HAART less likely to transmit the virus.

Unlike the other models reviewed here, this model is parameterized in terms of an HIV transmission probability *per partnership* rather than an HIV transmission probability *per act of sex*. This means that the probability of HIV transmission is determined at the inception of the partnership, rather than over the course of the partnership. Additional allowance is made, though, for HIV transmission to occur after inception of the partnership if the one partner is infected by an outside partner during the course of the partnership.

Other STDs are not modelled, although it is assumed that improved treatment for STDs would lead to a reduction in the probability of HIV transmission per partnership.

**Modelling sexual behaviour**

The approach adopted is to divide the sexually active population into two different vaccine classes. Women are classified as being either sex workers or 'low risk', while men are classified as being either clients of sex workers or 'low risk'. These divisions are not static, i.e. individuals can move between risk groups over time. Contact between sex workers and their clients are therefore assumed to be one of the major factors driving the epidemic. No allowance is made for possible increases in risk-taking behaviour after HAART becomes available. The sexually active population modelled corresponds roughly to the 15 to 59 year old population, and since the model does not divide the sexually active population by age, it implicitly assumes that sexual behaviour is independent of age.

Female sexual behaviour is determined as a function of male 'demand' – i.e. the rates at which women enter the 'sex worker' group and the rates at which women form 'long term' partnerships are set to meet the male 'demand' for such relationships.

Condom usage is modelled only in the context of relationships between sex workers and their clients.

**Modelling HIV survival**

The time from HIV infection to death is split into two phases: the pre-AIDS phase (the mean term spent in this stage is assumed to be 6.5 years) and the AIDS phase (individuals are assumed to survive in this stage for one year on average). If individuals start HAART, it is assumed that they survive four years on average before developing drug resistance, after which it is assumed that they experience the same rate of progression to AIDS as untreated individuals (the assumption made is that only one treatment regimen is offered and there is no 'second line' or salvage regimen offered to people who develop resistance to the drugs in the regimen). The model therefore assumes that the mean time from HIV infection to death (in the absence of non-AIDS mortality) is 7.5 years if the infected individual does not have access to HAART and 11.5 years if the infected individual does start HAART. HAART is assumed to be initiated two years after the individual is infected, on average.

**Ease of use**

The project team has no experience of using the model, but on the basis of the information to hand, its lack of demographic and epidemiological sophistication cannot be relied upon to accurately project the population of a country.

### A2.2.5 Spectrum and EPP (Epidemic Projection Package)

**Brief description of Spectrum and EPP**

Spectrum is a compiled Windows-based suite of programs to assist policymakers in deciding policy questions related to population dynamics. It was developed and is maintained by "The Futures Group International" and can be freely downloaded from their website (www.futuresgroup.com). The system consists of the following components:

- **DemProj** - cohort component projection model (projects on the basis of base population and assumptions of fertility, mortality and migration)
- **FamPlan** - to project family planning needs

- **Benefit-Cost** – cost-benefit analysis of family planning programme
- **AIDS Impact Model (AIM)** - program to project consequences of AIDS
- **RAPID** – socio-economic consequences of high fertility
- **Adolescent reproductive health (NewGen)** – A program to estimate the consequences of adolescent reproductive health behavior
- **Prevention of mother-to-child transmission (PMTCT)** – A program to examine the costs and benefits of interventions to prevent the transmission of HIV from mother to child

In order to project the demographic impact of HIV/AIDS a user must first use DemProj to produce a population projection that does not take HIV/AIDS into account, and then apply AIM to incorporate the impact of HIV/AIDS. AIM works via curve-fitting routine applied to a series of prevalence rates of HIV among adults (males and female 15-49 combined) for the whole projection period from the start of the epidemic. In other words, the prevalence outputs of the model are – in fact –inputs into the model. The UNAIDS/WHO Reference Group on Estimates, Modelling and Projection has developed a software package (compiled in Java) for fitting a curve to observed prevalence rates from a country which is then used to project the prevalence rates forward. Other future prevalence assumptions can also be used, but the results of the model remain completely determined by the user's view of the future course, level and extent of HIV prevalence in the adult population.

As inputs, DemProj requires a base population; past and future total fertility rates; life expectancies at birth; and numbers and age distribution of net immigrants. In addition, the user has to choose from a set of standard mortality and fertility tables the one with the 'shape' closest to that of the country being modelled.

Where users are less certain of these input requirements, the software allows users to make use of "Easy Proj" which constructs a projection using estimates based on the UN Population Division's most recent projections for the country as inputs. However, recent research has shown some significant flaws in these input estimates (Mulder and Johnson, 2005). The software also allows for one to make use of user-defined 'shapes' of fertility and mortality rates by age, although in the case of mortality this involves editing two of the input files and is not for the novice user.

Although DemProj projects the population by single calendar years and in single years of age the base population, fertility, mortality and migration are for the most part in five-year age groups and single year rates and numbers have to be derived from these data.

AIM derives the number of people newly infected with HIV in any year from the adult prevalence rates. To do so, an assumption has to be made about the ratio of female to male prevalence in each year to give female and male adult prevalence rates, then assumptions are made as to the ratio of the prevalence in specific age groups to that in the 25-29 year age group in each year to give prevalence rates by age. Differencing of the year-on-year prevalence rates (allowing for mortality) gives an estimate of incidence rates, which in turn are used to estimate the number of newly infected HIV cases each year. Through the use of assumptions about proportion of those infected who die after one, two, etc years of being infected, AIM can thus produce estimates of the number of AIDS deaths each year by age for each of the sexes. These are then incorporated into the demographic projection.

AIM also allows for assumptions to be made for the relationship between HIV and fertility (which are assumed to be constant over time) and for an amelioration of the impact due to the provision of ART and PMTCT. Most of these assumptions can be replaced by the user, although most users would probably be forced, through lack of country-specific estimates, to accept the default assumptions.

The advantages of Spectrum are:

- It is relatively simple to use
- Projections can be produced with the very minimum of user input
- Being compiled it runs quickly and the program cannot be accidentally or intentionally altered
- It is the package used by UNAIDS/WHO so its use would encourage conformity with their results.

Its disadvantages are:

- The demographic and epidemiological projections are independent; indeed it is possible to simply make up the prevalence rates used as input for AIM. Thus there is nothing that ensures consistency between the two, and it is possible that changes are occurring in the one that are incompatible with the output being produced in the other. This becomes a particular concern with the introduction of ART, which is allowed for (although somewhat crudely) in AIM but not in EPP. And since AIM needs as input projections of prevalence levels into the future it is entirely possible that these may imply a level of ART different from that assumed in AIM.
- Using quinquennial input to approximate numbers by individual ages leads to inevitable approximations which could be particularly problematic at advanced ages.
- Because of these design limitations this package is not designed to produce long term projections.
- Being a compiled program there is a limit to the output one can readily produce.
- The model is necessarily simple to make maximum use of limited data. Thus it does not segment the population into higher and lower risk groups. In particular it does not allow for the impact of STDs on the epidemic. Thus one is unable to incorporate the impact of saturation or treatment/behaviour change in these groups.
- The modelling of interventions is limited. Although there is a separate package “GOALS” which can be used to cost the impact of different interventions which

works with the output from Spectrum, it too is independent and thus there is nothing to ensure that assumptions are consistent between the two packages.

**Ease of use**
Spectrum/EPP is a very useful tool which is freely available and does not require a high level of skill to run. It also does not require much data if one is prepared to accept the default assumptions. However, in countries which have more than the minimum amount of data on the epidemic it is likely to be more useful to apply a more sophisticated model both to investigate the impact of various treatment and prevention scenarios but also to do longer term projections.

The single greatest weakness of the Spectrum/EPP approach is that future dynamics of the epidemic are themselves governed by the user's (or, in the case of the default assumptions., the UN's) view of the future of the epidemic rather than this being one of the main outputs from the model. A secondary limitation is that there is a disconnect between EPP and AIM, making it possible to produce inconsistent results.

## A2.3 Comparisons and conclusions

This section highlights some of the features of the various models reviewed, and weighs them against the two fundamental criteria that users should seek to satisfy themselves of before choosing one model over another.

### A2.3.1 Needs of the user

The needs of the user, as outlined in section A2.1.1, include the ability to perform sub-national, in addition to national, projections; to assess the implications of interventions on the future course of the epidemic; and the provision of sufficient detail for assessing the economic impact of the epidemic and for health management.

All these needs are easily satisfied by the ASSA2003 model. Sub-national projections are easily produced. Furthermore, the implication of interventions on the future course of the epidemic are easily determined as interventions are allowed for directly. In addition, the ASSA model is highly flexible and easily customized to produce additional output for assessing the economic impact of the epidemic and for health management

SimulAIDS is likely not be appropriate for meeting the needs of the user as simulation models are difficult to apply to populations of more than 10 000 to 20 000 individuals. Thus, output produced by this model may not be of sufficient quality for assessing the implications of interventions on the future course of the epidemic. However, this model is able to produce various detailed output.

For reasons similar to those advanced in favour of the ASSA2003 model, both iwgAIDS and Spectrum/EPP may satisfy most user needs. The impact of the epidemic can be analyzed along a number of demographic and epidemiological dimensions. Furthermore, interventions can be allowed for directly and their impact on the epidemic assessed.

Nico Nagelkerke's model, however, has limited use from a demographic point of view as it is not structured by age. Thus, sufficient output for assessing the economic impact of the epidemic and for health management is likely not to be available.

### A2.3.2 Availability of Data

The ASSA2003 model requires various demographic, epidemiological and behavioural assumptions. A great deal of data are required for determining these assumptions, however, these assumptions can be justified for Botswana and readily available from the given data.

It is not feasible to apply SimulAIDS to Botswana due to the large data requirements:. individual-based stochastic HIV/AIDS models require many more parameters than deterministic models. It is likely that there are not sufficient data for Botswana to satisfy all these parameters. iwgAIDS, being a complex model, also requires a large number of input parameters which is not justifiable for Botswana.

Nico Nagelkerke's model, however, has relatively few input requirements. Furthermore, the demographic assumptions required are minimal. Thus, this model will not be difficult to parameterize given the available data for Botswana.

Spectrum's data requirements are not much different from that of ASSA, with the important exception that the user needs to assume a future course for the epidemic.

### A2.3.3 Conclusion

A large number of models have been investigated in this Appendix. However, all but two are either over-simplified (e.g. Nagelkerke) or overly complicated (e.g. iwgAIDS). The choice is therefore between Spectrum and ASSA. Given the performance of each, as described above, in terms of flexibility, transparency and usability, it is concluded that the most adequate model for estimating the demographic impact of HIV/AIDS in Botswana is the ASSA2003 model.

However, should it be deemed useful, a set of input parameters can easily be created from the ASSA model to be used in Spectrum to generate materially the same results.

# APPENDIX 3
# PROPRIETARY MODELS USED TO PROJECT THE POPULATION OF BOTSWANA

## A3.1 Introduction

The purpose of this Appendix is to review the various projections of the impact of the AIDS epidemic in Botswana produced by models that are not publicly available. This is important as a check on the results produced by any model chosen for this project. (A subsidiary benefit is that the extent of divergences between the results from the various models provides, to the extent that the models are reasonable, some important insight into the extent of uncertainty surrounding the future course of the HIV/AIDS epidemic in Botswana.)

The various projections of the epidemic are reviewed in the following section. Thereafter, the projections are compared and conclusions drawn.

## A3.2 Review of projections

### A3.2.1 UNAIDS/WHO

**Table A3.1 Current Indicators from UNAIDS/WHO model**

| | | | |
|---|---|---|---|
| **Estimated number of adults and children living with HIV/AIDS (end 2003):** | | | |
| | Adults and children | 350,000 | (330,000 –380,000) |
| | Adults (15-49) | 330,000 | (310,000 – 340,000) |
| | Children (0-15) | 25,000 | (17,000 – 36,000) |
| | Women (15-49) | 190,000 | (180,000 – 190,000) |
| | HIV prevalence (Adults) (%) | 37.3 | (35.5 – 39.1) |
| **Estimated number of deaths due to AIDS (during 2003):** | | | |
| | Adults and children | 33,000 | (25,000– 43,000) |
| **Estimated number of AIDS orphans (children under age 17 who have lost their mother or father or both parents to AIDS) (end 2003):** | | | |
| | Current living orphans | 120,000 | (84,000 – 180,000) |
| **Demographic Indicators:** | | | |
| | Total population (thousands) (2004) | | 1,795 |
| | Female population aged 15-24 (thousands) (2004) | | 206 |
| | Population aged 15-49 (thousands) (2004) | | 910 |
| | Crude birth rate (births per 1,000 pop.) (2004) | | 29.7 |
| | Crude death rate (deaths per 1,000 pop.) (2004) | | 24.7 |
| | Maternal mortality rate (per 100,000 live births) | | 100 |
| | Infant mortality rate (per 1,000 live births) (2000) | | 60 |
| | Under 5 mortality rate (per 1,000 live births) (2000) | | 93 |
| | Life expectancy at birth (years) (2002) | | 40.4 |
| | Total fertility rate (2002) | | 3.7 |

The UNAIDS/WHO use Spectrum to carry out their projections. However, the full projections are not published, and only summary results, in the form of current indicators, are published. The latest round of indicators for Botswana was published in 2004. These are shown in the table above.

### A3.2.2 Nico Nagelkerke's model

The model projections prepared by Nagelkerke *et al* (2001) for the WHO Commission on Macroeconomics and Health suggest that the prevalence of HIV in the 15-59 year old population was around 28% in 2003, and that this would ultimately rise to just less than 40% in the absence of HIV interventions. HIV incidence rates are estimated to follow similar trends, rising from about 6.4% in 2003 to just under 7% in the longer term, in the absence on interventions. The proportion of births in which HIV transmission occurs is estimated to be around 9% in 2003, and would rise to almost 12% in the absence on intervention.

### A3.2.3 UN Population Division

The UN Population Division produces population projections for each country in the world. It makes use of its own Abacus software incorporating a module, abcDIM, which - structurally - is a combination of EPP and Spectrum. The projections are constrained to ensure that results do not contradict those produced by UNAIDS, and UNAIDS use the non-AIDS projections as input into the DemProj component of Spectrum. More detail is provided in Mulder and Johnson (2005).

### A3.2.4 US Census Bureau

The US Census Bureau, International Programs Center, produce projections of the populations of many overseas countries. These projections are produced using a modification of RUP software (which is somewhat dated publicly available software for producing urban-rural projections without HIV/AIDS), with a module, RupHivAids, used much like AIM in spectrum, to incorporate the impact of the HIV/AIDS epidemic on mortality and fertility in future. By and large the assumptions in RupHivAids are the same as used by the UNAIDS. More detail is provided by Mulder and Johnson (2005).

**Table A3.2 Current Indicators: UN estimates for Botswana 2000-2020, medium variant**

| Indicator | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| Population (thousands) | 1 754 | 1 765 | 1 729 | 1 690 | 1 671 |
| Male population (thousands) | 859 | 867 | 861 | 854 | 856 |
| Female population (thousands) | 895 | 898 | 869 | 836 | 815 |
| Population sex ratio (males per 100 females) | 96.0 | 96.6 | 99.1 | 102.2 | 105.0 |
| Percentage aged 0-4 (%) | 13.3 | 12.4 | 11.8 | 11.8 | 11.6 |
| Percentage aged 5-14 (%) | 25.8 | 25.3 | 24.1 | 22.9 | 22.9 |
| Percentage aged 15-24 (%) | 23.0 | 24.4 | 25.4 | 25.2 | 23.6 |
| Percentage aged 60 or over (%) | 4.4 | 5.1 | 6.2 | 7.3 | 8.0 |
| Percentage aged 65 or over (%) | 2.8 | 3.3 | 4.0 | 4.8 | 5.6 |
| Percentage aged 80 or over (%) | 0.3 | 0.4 | 0.5 | 0.6 | 0.8 |
| Percentage of women aged 15-49 (%) | 51.7 | 51.1 | 50.6 | 50.7 | 51.3 |
| Median age (years) | 19.4 | 19.9 | 20.5 | 21.1 | 21.7 |
| Population density (per sq. km) | 3 | 3 | 3 | 3 | 3 |

| Indicator | 2000-2005 | 2005-2010 | 2010-2015 | 2015-2020 |
|---|---|---|---|---|
| Population change per year (thousands) | 2 | -7 | -8 | -4 |
| Births per year, both sexes combined (thousands) | 47 | 44 | 42 | 40 |
| Deaths per year, both sexes combined (thousands) | 44 | 50 | 48 | 42 |
| Population growth rate (%) | 0.12 | -0.41 | -0.45 | -0.23 |
| Crude birth rate (per 1,000 population) | 26.9 | 25.0 | 24.3 | 23.7 |
| Crude death rate (per 1,000 population) | 25.0 | 28.4 | 28.1 | 25.3 |
| Total fertility rate (children per woman) | 3.20 | 2.92 | 2.70 | 2.53 |
| Net reproduction rate (per woman) | 0.97 | 0.85 | 0.84 | 0.87 |
| Infant mortality rate (per 1,000 births) | 51.0 | 42.6 | 30.9 | 24.2 |
| Life expectancy at birth, both sexes combined | 36.6 | 33.9 | 34.8 | 38.4 |
| Life expectancy at birth, males | 36.0 | 35.0 | 36.7 | 40.8 |
| Life expectancy at birth, females | 37.1 | 32.7 | 32.9 | 35.8 |

*Source*: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, *World Population Prospects: The 2004 Revision* and *World Urbanization Prospects: The 2003 Revision*, http://esa.un.org/unpp

## Table A3.3 IDB Summary Demographic Data for Botswana, 2005 and 2025

| | 2005 | 2025 |
|---|---|---|
| Births per 1,000 population.................... | 23 | 20 |
| Deaths per 1,000 population.................... | 29 | 32 |
| Rate of natural increase (percent)............. | -0.6 | -1.2 |
| Annual rate of growth (percent)................ | 0.0 | -0.5 |
| Life expectancy at birth (years)............... | 33.9 | 34.6 |
| Infant deaths per 1,000 live births............ | 55 | 53 |
| Total fertility rate (per woman)............... | 2.8 | 2.1 |

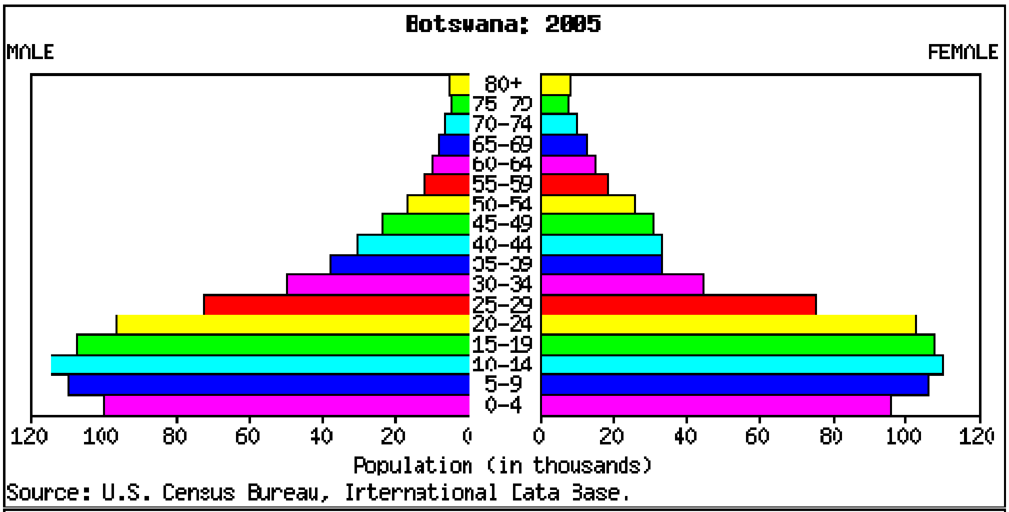
Midyear Population Estimates and Average Annual Period Growth Rates:
1950 to 2050 (Population in thousands, rate in percent)

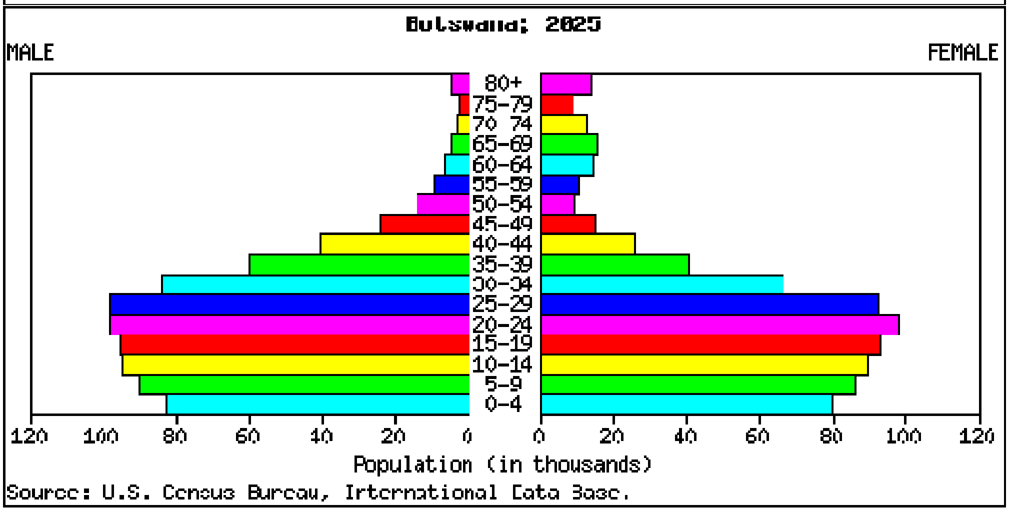
| Year | Population | Year | Population | Period | Growth Rate |
|---|---|---|---|---|---|
| 1950 | 430 | 2005 | 1,640 | 1950-1960 | 1.4 |
| 1960 | 497 | 2006 | 1,640 | 1960-1970 | 1.6 |
| 1970 | 584 | 2007 | 1,639 | 1970-1980 | 4.3 |
| 1980 | 900 | 2008 | 1,638 | 1980-1990 | 3.4 |
| 1990 | 1,264 | 2009 | 1,638 | 1990-2000 | 2.4 |
| 2000 | 1,607 | 2010 | 1,637 | 2000-2010 | 0.2 |
| 2001 | 1,621 | 2020 | 1,617 | 2010-2020 | -0.1 |
| 2002 | 1,630 | 2030 | 1,537 | 2020-2030 | -0.5 |
| 2003 | 1,636 | 2040 | 1,452 | 2030-2040 | -0.6 |
| 2004 | 1,639 | 2050 | 1,412 | 2040-2050 | -0.3 |

Midyear Population, by Age and Sex: 2005 and 2025
(Population in thousands)

| | 2005 | | | 2025 | | |
|---|---|---|---|---|---|---|
| AGE | TOTAL | MALE | FEMALE | TOTAL | MALE | FEMALE |
| TOTAL | 1,640 | 802 | 838 | 1,583 | 810 | 773 |
| 0-4 | 196 | 99 | 96 | 162 | 82 | 80 |
| 5-9 | 215 | 109 | 106 | 176 | 90 | 86 |
| 10-14 | 225 | 114 | 111 | 184 | 94 | 90 |
| 15-19 | 215 | 107 | 108 | 188 | 95 | 93 |
| 20-24 | 199 | 96 | 103 | 196 | 98 | 98 |
| 25-29 | 148 | 73 | 75 | 190 | 98 | 92 |
| 30-34 | 94 | 49 | 44 | 150 | 84 | 67 |
| 35-39 | 71 | 38 | 33 | 101 | 60 | 41 |
| 40-44 | 63 | 30 | 33 | 67 | 40 | 26 |
| 45-49 | 54 | 23 | 31 | 39 | 24 | 15 |
| 50-54 | 43 | 17 | 26 | 23 | 14 | 9 |
| 55-59 | 30 | 12 | 18 | 19 | 9 | 10 |
| 60-64 | 24 | 9 | 15 | 21 | 6 | 14 |
| 65-69 | 21 | 8 | 13 | 20 | 4 | 15 |
| 70-74 | 16 | 6 | 10 | 16 | 3 | 13 |
| 75-79 | 12 | 5 | 7 | 11 | 2 | 9 |
| 80+ | 13 | 5 | 8 | 19 | 5 | 14 |

Source: U.S. Census Bureau, International Data Base, April 2005 version.




#### A3.2.5 <u>Sanderson</u>

Warren Sanderson in attempting to determine whether prevention was more effective than treatment created a dynamic model of the epidemic in Botswana ref?. Although this is a sophisticated approach to addressing the problem its application was demographically and epidemiologically a little naïve, and while this might not invalidate the main purpose of the research it does call into question the reliability of the estimates produced as a result of this work.

### A3.3 Comparisons and conclusions

Although the models produce quite different estimates of the demographic impact of HIV/AIDS all, in common, show it to have a significant impact which is expected to result in a decline in population numbers in future. This is consistent with the previous report but not with the estimates produced as part of the current project or with the recently released UNAIDS estimates (UNAIDS 2006), which suggest that the impact is likely to be substantially lower.

# APPENDIX 4
# BASIS FOR FERTILITY ESTIMATION

### A4.1 Background

Estimates of fertility are required, by single year of age, for each year of the projection period. Since the incorporation of HIV/AIDS into a projection of the Botswana population requires that the projection commence in 1980, this means that estimates of fertility in the country need to go back at least as far as that, and must cover – at least – the duration of the projection going forward. Further, since the model being proposed projects the population of each census district of Botswana separately, this necessitates that single-year, single-age estimates of fertility are required at a level of disaggregation beneath the national.

This appendix sets out the approach used to derive fertility rates as used in the model.

### A4.2 Data sources

Despite its willingness to help, the CSO was unable to provide us with all the information we requested, in particular with metadata and/or questionnaires for the Demographic and Family Health Surveys. From the reports, as well as the underlying data made available to us, it is evident that the fertility estimates produced using data collected in various demographic enquiries are understated. Further, the sample sizes of these surveys were too small for the purposes of estimating sub-national trends in and levels of fertility.

We were fortunate to be provided with unit record data from both the 1991 and 2001 censuses, together with a copy of the Analytical Reports, the questionnaire, and limited metadata for these two censuses. Although the unit records of the 1981 census are no longer available electronically, we were provided with a copy of the Analytical Report from the 1981 census.

### A4.3 Published estimates of national fertility from the 1981, 1991 and 2001 censuses

The table below shows the published national total fertility rates for Botswana from the three most recent censuses. Estimates cited in Table 1.1 of the 2001 Analytical Report are shown in bold. From this it can be seen that there is a degree of inconsistency in the estimates of fertility published in the various Analytical Reports.

For each census, a range of estimates has been published in the Analytical Reports. Typically, the lowest estimates presented are those that have not been corrected for underreporting of children under the age of 1 in the census. However, as can be seen from the estimates in the column for 1981 (the estimate of 6.2 for 1981 is repeated in the 1991 report) occasionally even these unadjusted estimates get presented in subsequent census reports without it being made explicit or clear to the reader that these are, in fact, unadjusted (for under-reporting of births or for the length of the reference period) estimates. The estimate for 1981 (6.6 children per woman) presented in the 2001 report does not appear in the 1981 report and no explanation is given as to the method of its derivation in the 1991 report, or subsequently.

While the range of estimates in 1981 is less than one child per woman, it spans more than two children per woman in 1991. It is apparent from the 1991 Analytical Report that many methods of estimating fertility were applied to the data, although the periods to which the estimates refer are only infrequently explicitly defined. No reasons are given for why the method that produced the estimate of 4.2 children per woman was deemed preferable to the others.

As a consequence of the wide range of estimates available, further effort must be expended: first to understand the provenance of the various estimates, and second to decide on the appropriate level of fertility in the country at each of the census dates.

**Table A4.1 Estimates of fertility in 1981, 1991 and 2001 as indicated in official CSO documents**

| Estimate for 1981 | | 1991 | | 2001 | |
|---|---|---|---|---|---|
| 6.2 | a1 | 3.2 | b1* | 2.6 | c1** |
| 6.2 | b | 4.2 | b3 | **3.3** | c3 |
| 6.6 | d5 | **4.2** | c | | |
| **6.6** | c | 4.5 | b2 | | |
| 7.1 | a2 | 4.7 | b4 | | |
| 7.1 | b | 5.2 | d5 | | |
| | | 5.4 | b2 | | |

Sources and Methods
(a) 1981 Analytical Report
(b) 1991 Analytical Report
(c) 2001 Analytical Report
(d) CSO Website: www.cso.gov.bw/html/census/pop_cens_tbl4.html

(1) Adjusted for reference period
(2) Derived using Brass P/F ratio
(3) Adjusted using Rele's method
(4) Adjusted using Arraiga's method
(5) Method unspecified

Notes *: The presentation of the figure of 3.2 children per woman in the 1991 analytical report suggests that this figure has been adjusted for reference period error. Inspection of the unit record data shows that this figure has not been adjusted as described. The adjusted rate is 3.6 children per woman.
**: Based on incorrect reference period adjustment factor. 1.091 used instead of 1.137

As is pointed out on page 15 of the 2001 Analytical Report, there was an evident undercount of children, of at least 8.1 percent, aged under the age of 5 in 1991[*]. Further, page 11 of the Analytical Report, and Graph 10 (on page 12) both suggest that, as in 1991, there was an undercount of children aged 0-4 in the 2001 census as well.

The method used to derive the most commonly cited estimates of fertility in both 1991 and 2001 is singularly inappropriate. The method, Rele's Technique, is highly dependent on the

[*] The figure is at least 8.1 per cent, since the logic of that first paragraph, indicating an undercount of 193 712 / 210 694, ignores any mortality of children aged 0-4 in 1991 over the following decade. The 210 694 are the survivors of children aged 0-4 in 1991.

enumerated population of children aged 0-4. This is because the primary input required by the method is the child-woman ratio (CWR), defined as

$$CWR = \frac{\text{Children aged } 0-4}{\text{Women aged } 15-49}.$$

From this the total fertility rate (TFR) is estimated by means of a linear equation, $\text{TFR} = a + b.\text{CWR}$, where *a* and *b* are derived by interpolation between tabulated coefficients of *a* and *b* for given values of $e_0$=20, 30,…, 70.

As should be obvious from the method's assumption of a linear relationship between the TFR and CWR, any undercount of children aged 0-4 without a corresponding undercount of women of reproductive age will result in a CWR that is understated and consequently lead to an underestimation of the TFR. Moreover, it can be shown that the technique compounds reporting errors when the life expectancy at birth is greater than approximately 46.85 years (since the tabulated values of alpha are monotonically decreasing, and turn negative at about this point). It is further worth quoting the opinion of the originator of the technique:

> Among the weaknesses of the methodology, the derived fertility estimates depend directly on the accuracy of the CWRs. Thus, the methodology, when applied to developed countries, gives excellent results. In developing countries, however, the results may be affected by errors in age reporting, especially underreporting of the number of young children in the age group 0-4 years. (Rele, 1993:11-48)

A further problem with the method relates to the fact that a generalised HIV/AIDS epidemic distorts the age distribution of mortality, and hence using a model life table that does not include the impact of HIV/AIDS will produce a particular life expectancy at birth that will overestimate the extent of child mortality relative to adult mortality, and hence overestimate the fertility rate if this method is used. The magnitude of these two effects, which run in opposite directions, is not easily quantified. However, since AIDS-related mortality was probably relatively low in 1991, one can conclude that, *ceteris paribus*, the magnitude of the understatement of fertility was greater in 1991 than in 2001.

In any event, these shortcomings offer compelling reasons why this method should not be applied to the census data from Botswana to estimate fertility rates in that country. Hence, the published fertility levels for 1991 and 2001 (of 4.2 and 3.3 children per woman, respectively) are unlikely to be a true reflection of the level of fertility in the country at either time.

In passing, if one applies Rele's technique to the life expectancy at birth and child woman ratio for 1981 as reported in Table 1.1 of the 2001 Analytical Report, an estimate (again, known to be too low) of fertility in 1981 of 6.2 children per woman is obtained.

## A4.4 Derivation of estimates of fertility for Botswana in 1981, 1991 and 2001

In order to estimate fertility levels and trends from the Botswana census data, then, other methods have to be employed. The preferred approach is to use the Relational Gompertz model. The Relational Gompertz model is a successor to the P/F ratio method, but it does not require the same assumption about constant fertility. Further, it allows errors in the data to be identified and assessed (Booth 1984; Zaba 1981)

The inputs to the Relational Gompertz model are the same as that for the P/F ratio method, namely tabulations of observed age-specific fertility rates and average parities in each age group. In the case of the 1991 and 2001 censuses, these inputs were derived from the data. While the same number of reported births in the last year were identified as reported in the 2001 Analytical Report, the scaling factor used to address the reference period error stated in the report is incorrect. The Analytical Report suggests that the adjustment factor should be 12/11 or 1.091. Allowing for the precise number of days between Independence Day and the assumed census date (17 August 2001) requires that the adjustment factor be 1.137. Even in the absence of any other differences, this would result in an underestimate of fertility by 4.2%.

The table below shows the age-specific fertility rates and average parities for Botswana nationally, as derived directly from the data in the 1991 and 2001 censuses.

**Table A4.2 Input data for estimating fertility in Botswana in 1991 and 2001 using a Relational Gompertz model**

| | 1991 | | 2001 | |
|---|---|---|---|---|
| Age group | ASFR | Average parity | ASFR | Average parity |
| 15-19 | 0.062 | 0.185 | 0.042 | 0.134 |
| 20.24 | 0.153 | 1.142 | 0.123 | 0.859 |
| 25-29 | 0.150 | 2.296 | 0.111 | 1.686 |
| 30-34 | 0.134 | 3.524 | 0.106 | 2.661 |
| 35-39 | 0.115 | 4.635 | 0.087 | 3.617 |
| 40-44 | 0.072 | 5.599 | 0.051 | 4.576 |
| 45-49 | 0.031 | 6.091 | 0.020 | 5.272 |
| TFR | 3.58 | | 2.70 | |

Applying the Relational Gompertz model to these data, judiciously selecting which of the ASFRs and average parities to include in the model, leads to revised estimates of the fertility level in Botswana of 5.4 children per woman in 1991, and 4.0 in 2001. This represents an increase of approximately 28 per cent over the rate published in the Analytical Report for 1991, and 21 per cent over that published for 2001, and confirms the observation above that the distortions in the estimated fertility rate arising from undercounts of children under the age of 5 and the use of Rele's method are ameliorated in the presence of significant HIV/AIDS-related mortality. (Incidentally, the magnitude of the increase from the estimate unadjusted for under reporting of births and reference period adjustment error to the revised estimate is of the order of 50 per cent in both 1991 and 2001. This suggests that only about two-thirds of the births that occurred in the period before each census were actually reported as such in the census, and provides further evidence of a significant undercount of children under the age of five in both censuses.)

### A4.5 Regional estimates of fertility from the 1991 and 2001 censuses

The derivation of an accurate model for projecting the Batswana population requires that regional populations are modelled independently, and then aggregated to give national estimates. In turn, this requires that fertility estimates are derived for each of these regional populations. This is in contrast to the sub-national estimates presented in the 1981, 1991 and 2001 Analytical Reports, which give only estimates for urban and rural areas.

However, childbearing is a relatively rare event, and hence it is not possible to derive consistent and plausible estimates of fertility for all 28 census sub-districts. Instead, estimates were derived for each of the seven urban centres, and for the nine administrative districts. The mapping of the census sub-districts onto the administrative districts is shown in the table below.

**Table A4.3 Mapping of census districts onto areas used to estimate fertility in 1991 and 2001**

| Area | 2001 Census sub-district (Code in brackets) |
|---|---|
| Gaborone | Gaborone (01) |
| Francistown | Francistown (02) |
| Lobatse | Lobatse (03) |
| Selebi-Phikwe | Selebi-Phikwe (04) |
| Orapa | Orapa (05) |
| Jwaneng | Jwaneng (06) |
| Sowa Pan | Sowa Pan (07) |
| Southern | Ngwaketse (10)<br>Barolong (11)<br>Ngwaketse West (12) |
| South-East | South-East (20) |
| Kweneng | Kweneng East (30)<br>Kweneng West (31) |
| Kgatleng | Kgatleng (40) |
| Central | Serowe-Palapye (50)<br>Mahalapye (51)<br>Bobonong (52)<br>Central Boteti (53)<br>Tutume (54) |
| North-East | North-East (60) |
| North-West | Ngamiland East (70)<br>Ngamiland West (71)<br>Chobe (72)<br>Delta (73) |
| Ghanzi | Ghanzi (80)<br>CKGR (81) |
| Kgalagadi | Kgalagadi South (90)<br>Kgalagadi North (91) |

A Relational Gompertz model was fitted separately to each area in each census, 32 models in total. The resulting schedules of age-specific fertility rates were then weighted by the number of women in each age group, and in each area, to derive a revised national estimate of fertility. Because the input points selected for inclusion were not the same for all 16 areas in each census, the national estimate derived as a weighted average of fertility in the 16 areas differs slightly from that derived nationally, although not to a material degree. A comparison of the national estimates, for both censuses, derived directly and as a weighted average of the 16 regions is shown below.

**Table A4.4 Estimates of national fertility in Botswana using two methods, 1991 and 2001**

| | 1991 | | 2001 | |
|---|---|---|---|---|
| Age group | ASFR (direct) | ASFR (weighted) | ASFR (direct) | ASFR (weighted) |
| 15-19 | 0.109 | 0.131 | 0.079 | 0.087 |
| 20.24 | 0.223 | 0.221 | 0.170 | 0.171 |
| 25-29 | 0.242 | 0.231 | 0.184 | 0.184 |
| 30-34 | 0.221 | 0.212 | 0.165 | 0.168 |
| 35-39 | 0.178 | 0.178 | 0.130 | 0.136 |
| 40-44 | 0.096 | 0.104 | 0.067 | 0.073 |
| 45-49 | 0.016 | 0.020 | 0.010 | 0.012 |
| TFR | 5.42 | 5.48 | 4.03 | 4.15 |

Estimates of total fertility in each of the 16 areas in 1991 and 2001 are shown in Table A4.5.

**Table A4.5 Estimates of fertility in Botswana by area, 1991 and 2001**

| Area | 1991 | 2001 |
|---|---|---|
| Gaborone | 4.3 | 3.2 |
| Francistown | 5.2 | 3.8 |
| Lobatse | 4.9 | 3.3 |
| Selebi-Phikwe | 4.9 | 3.5 |
| Orapa | 4.4 | 3.4 |
| Jwaneng | 3.8 | 3.8 |
| Sowa Pan | 4.7 | 3.6 |
| Southern | 6.2 | 4.3 |
| South-East | 4.0 | 3.3 |
| Kweneng | 6.5 | 4.4 |
| Kgatleng | 5.0 | 3.7 |
| Central | 5.9 | 4.6 |
| North-East | 6.1 | 4.4 |
| North-West | 5.8 | 5.1 |
| Ghanzi | 5.0 | 4.8 |
| Kgalagadi | 5.1 | 4.3 |

## A4.6 Estimation of fertility in 1981

The process of estimating fertility rates for the 1981 census, nationally and by area, was complicated by the fact that unit record data were not available. Hence, all we had to go on was the Analytical Report from that census that gave basic data, on age-specific fertility rates and average parities, for urban and rural areas and for the country as a whole. From these data it is apparent that all estimates for 1981 presented in the 1991 report are derived from the estimates presented in the 1981 report before they were adjusted for under reporting of birth using the Brass P/F ratio. Moreover, the value of 6.6 children per woman, presented in the 1991 report as being the TFR in Botswana in 1981, is inconsistent with the urban and rural estimates presented in that report (which correspond to those in the 1981 report and a TFR of 7.1, but which would require that approximately half the population in Botswana in 1981 was urbanised to produce the national estimate of 6.6).

While the use of the Brass P/F method in 1981 is understandable given the early stage of the Botswana fertility decline at that time, the Relational Gompertz model is more appropriate. Application of the Relational Gompertz method suggests national, urban and rural levels of fertility of 6.5, 5.3 and 6.7 respectively in 1981. Thus, the estimates of fertility – nationally, urban and rural – in 1981 are as shown in the last line of Table A4.6.

**Table A4.6 Estimates of fertility in Botswana by urban and rural residence, 1981**

| | National | Urban | Rural |
|---|---|---|---|
| 1981 Analytical Report | 7.1 | 6.0 | 7.3 |
| 1991 Analytical Report | 6.6* | 6.0 | 7.3 |
| Estimated | 6.5 | 5.3 | 6.7 |

* See text for commentary

In order to derive estimates of fertility by area from the 1981 data, with only these three figures, a series of assumptions has to be made. It is apparent from Table A4.5 that there were significant differences in fertility between areas in Botswana in 1991 that are not accounted for by their urban and rural composition. Depending on the proportion of women of reproductive age living in rural and urban areas in each area, it is possible to derive an expected fertility rate for that area if urban/rural residence encapsulated and perfectly predicted fertility patterns. By dividing the observed fertility rates in each area by the expected fertility rate, a measure of the degree of deviation from the expected level of fertility is obtained. This measure can be considered as indicating the relative extent of the presence of other factors known to suppress or increase fertility in each area.

Data from the 1981 census was then obtained that showed the proportion of each census sub-district that was urban or rural. In 1981, only the defined urban areas had any urban population, with the exception of two very small areas: Palapye in the Central district (9 600 urban) and Tlokweng (6 700 urban) in the South-East (2001 Analytical Report, page 55). The population of Central and South-East district in 1981 is given as 323 329 and 30 648 respectively.[*] Hence, in the absence of the unit record data, one can assume that the Central district was roughly 3 per cent urban in 1981, and the South-East, 22 per cent urban. Using this information, and the urban and rural fertility rates above, total fertility rates for each area were derived in proportion to their urban-rural composition. These were then scaled using the scaling factors derived from the 1991 data. The implicit assumption made here is that the particular combination of factors that might lead a particular province to have higher (or lower) fertility than expected (given its urban/rural composition) apply in equal measure in 1981. This assumption is not

[*] Source: www.cso.gov.bw/html/census/pop_cens_tbl1.html

particularly problematic given the limited decline in fertility in the 1980s, and is – nonetheless – the best that can be done without access to the 1981 unit record data.

### A4.7 Derivation of schedules for use in the ASSA model

Once schedules for each area, for each of 1981, 1991 and 2001 had been derived, it remains to derive single-age, single-year estimates for each region, covering ages 10-49 and years from 1980 through to the end of the projection period.

For the period from 1981 to 2001, standardised fertility schedules were derived from the estimated fertility rates in each area, and linear interpolation applied (between 1981 and 1991, and 1991 and 2001 for years in each interval respectively) to generate a series of standardised age-specific fertility schedules for each year from 1981 to 2001.

Out-of-interval extrapolation was used to derive a schedule for 1980. (While such extrapolation is inherently risky, it was only required for a single year, so the magnitude of error introduced is not great). A less considered strategy had to be adopted for estimating the changing age pattern of fertility after 2001. After consideration, it was decided to allow fertility schedules in each area to trend towards a generic low-fertility pattern by 2035.

The ASSA model requires that fertility rates be presented as single-year estimates. Beers' formula (Shryock and Siegel 1976) was used to generate smooth schedules of fertility rates for individual ages between 10 and 49 each year using the quinquennial fertility schedules derived.

These fertility schedules then had to be scaled up to give an estimate of fertility levels each year. As with the shape of the fertility distribution, fertility levels in each area for each area covering the period 1981-2001 were also derived by interpolation. Exponential growth rates over the two ten year periods covered by the two censuses were derived, and used to estimate total fertility rates in each year. Fertility levels of 1980 were derived by exponential extrapolation from 1981 of the 1981-1991 change in fertility. Fertility rates after 2001 were considered in all regions to decline at an average of 3 per cent per annum until such time as a TFR of 2.2 children per woman was reached, where after fertility levels are presumed to be stable[*].

Table A4.7 shows the year in which fertility in each region is presumed to become stable. Nationally, substantial stability in the fertility rate will be achieved by 2023, although complete stability would obviously only be achieved at the point where the last region has achieved a stable fertility rate.

[*] In the model rates are allowed to continue declining asymptotically towards a limiting TFR of 1.62

**Table A4.7 Estimated year in which fertility attains the level of 2.2 children per woman**

| Area | Year |
|---|---|
| Gaborone | 2015 |
| Francistown | 2020 |
| Lobatse | 2015 |
| Selebi-Phikwe | 2017 |
| Orapa | 2016 |
| Jwaneng | 2020 |
| Sowa Pan | 2018 |
| Southern | 2024 |
| South-East | 2015 |
| Kweneng | 2025 |
| Kgatleng | 2019 |
| Central | 2026 |
| North-East | 2025 |
| North-West | 2030 |
| Ghanzi | 2028 |
| Kgalagadi | 2024 |

## A4.8 Summary

This section has set out to describe the process of estimating sub-national fertility trends and levels in Botswana covering the period 1980-2035. Table A4.8 shows a summary of estimated fertility rates for various years in each of the areas. The estimated total fertility rates in each of the 16 areas are also graphed in Figure A4.1.

**Figure A4.1 Total fertility rates in 16 Batswana areas, 1980-2020**

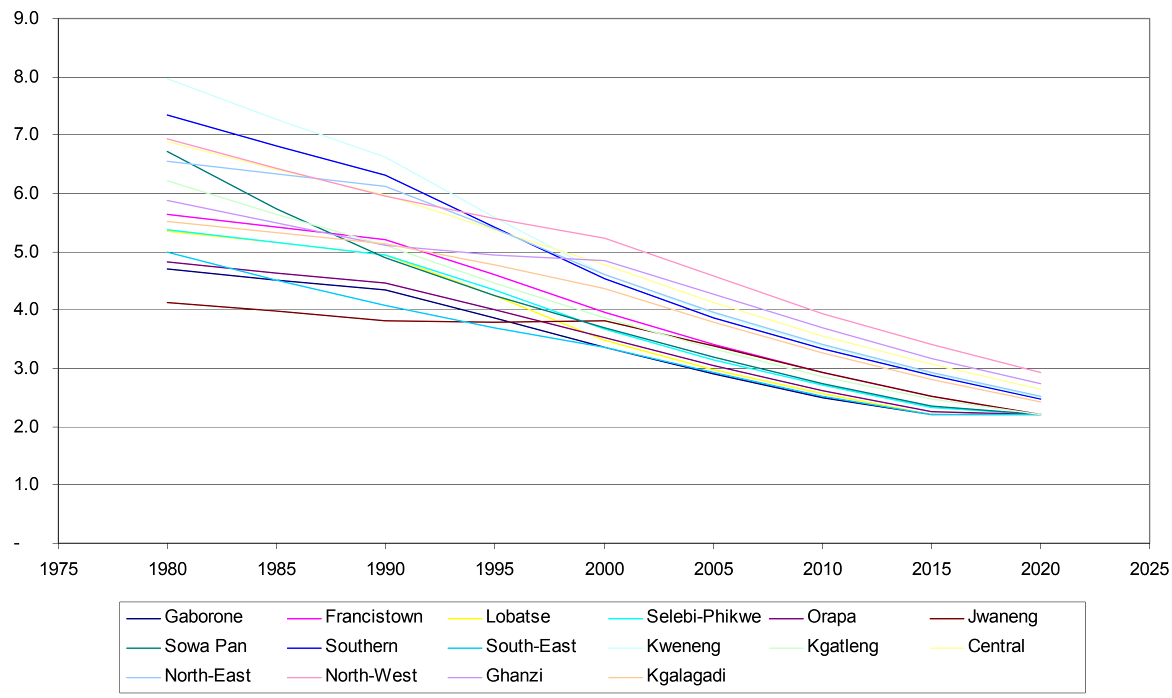


**Table A4.8 Age-specific fertility rates (per 1000 women) and TFRs, by area and selected years, 1980-2020**

| Gaborone | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 106 | 96 | 85 | 70 | 56 | 46 | 39 | 33 | 32 |
| 20-24 | 197 | 183 | 168 | 150 | 132 | 118 | 105 | 95 | 98 |
| 25-29 | 215 | 204 | 194 | 178 | 161 | 147 | 134 | 125 | 131 |
| 30-34 | 190 | 185 | 180 | 165 | 147 | 129 | 112 | 100 | 101 |
| 35-39 | 145 | 144 | 145 | 130 | 111 | 91 | 73 | 59 | 54 |
| 40-44 | 75 | 77 | 80 | 69 | 56 | 43 | 32 | 24 | 20 |
| 45-49 | 14 | 15 | 16 | 13 | 9 | 7 | 5 | 4 | 3 |
| TFR | 4.7 | 4.5 | 4.3 | 3.9 | 3.4 | 2.9 | 2.5 | 2.2 | 2.2 |

| Francistown | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 127 | 120 | 113 | 104 | 93 | 77 | 61 | 49 | 39 |
| 20-24 | 236 | 223 | 209 | 186 | 161 | 142 | 126 | 111 | 100 |
| 25-29 | 258 | 245 | 233 | 204 | 173 | 159 | 148 | 136 | 127 |
| 30-34 | 228 | 219 | 211 | 185 | 156 | 137 | 121 | 107 | 96 |
| 35-39 | 174 | 170 | 167 | 147 | 124 | 101 | 81 | 65 | 53 |
| 40-44 | 90 | 90 | 90 | 80 | 68 | 53 | 40 | 29 | 21 |
| 45-49 | 16 | 17 | 18 | 16 | 14 | 11 | 8 | 6 | 4 |
| TFR | 5.6 | 5.4 | 5.2 | 4.6 | 4.0 | 3.4 | 2.9 | 2.5 | 2.2 |

| Lobatse | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 121 | 112 | 104 | 91 | 78 | 64 | 51 | 41 | 38 |
| 20-24 | 224 | 206 | 186 | 169 | 152 | 134 | 117 | 102 | 103 |
| 25-29 | 245 | 228 | 210 | 188 | 166 | 150 | 137 | 125 | 131 |
| 30-34 | 216 | 208 | 199 | 171 | 141 | 123 | 108 | 95 | 97 |
| 35-39 | 165 | 166 | 168 | 136 | 102 | 82 | 67 | 54 | 50 |
| 40-44 | 86 | 92 | 100 | 76 | 50 | 37 | 28 | 21 | 18 |
| 45-49 | 16 | 19 | 23 | 16 | 8 | 6 | 4 | 3 | 3 |
| TFR | 5.4 | 5.2 | 4.9 | 4.2 | 3.5 | 3.0 | 2.6 | 2.2 | 2.2 |

| Selebi-Phikwe | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 121 | 116 | 112 | 96 | 78 | 63 | 51 | 42 | 37 |
| 20-24 | 224 | 214 | 204 | 181 | 157 | 137 | 121 | 106 | 102 |
| 25-29 | 245 | 234 | 223 | 200 | 174 | 158 | 145 | 132 | 131 |
| 30-34 | 217 | 208 | 199 | 176 | 151 | 132 | 116 | 102 | 98 |
| 35-39 | 165 | 160 | 154 | 134 | 111 | 91 | 73 | 59 | 51 |
| 40-44 | 86 | 84 | 82 | 69 | 55 | 42 | 32 | 24 | 19 |
| 45-49 | 16 | 16 | 16 | 12 | 9 | 7 | 5 | 4 | 3 |
| TFR | 5.4 | 5.2 | 5.0 | 4.3 | 3.7 | 3.2 | 2.7 | 2.3 | 2.2 |

| Orapa | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 109 | 98 | 87 | 68 | 50 | 41 | 35 | 30 | 29 |
| 20-24 | 202 | 200 | 199 | 179 | 157 | 137 | 120 | 104 | 103 |
| 25-29 | 221 | 222 | 225 | 212 | 195 | 174 | 155 | 138 | 139 |
| 30-34 | 195 | 191 | 188 | 175 | 160 | 140 | 121 | 104 | 102 |
| 35-39 | 149 | 139 | 128 | 114 | 100 | 82 | 67 | 54 | 50 |
| 40-44 | 77 | 67 | 57 | 47 | 38 | 30 | 23 | 18 | 15 |
| 45-49 | 14 | 11 | 8 | 6 | 4 | 3 | 2 | 2 | 2 |
| TFR | 4.8 | 4.6 | 4.5 | 4.0 | 3.5 | 3.0 | 2.6 | 2.3 | 2.2 |

| Jwaneng | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 93 | 103 | 115 | 93 | 63 | 50 | 42 | 35 | 30 |
| 20-24 | 173 | 181 | 192 | 178 | 157 | 139 | 124 | 110 | 99 |
| 25-29 | 189 | 186 | 184 | 186 | 191 | 178 | 161 | 145 | 133 |
| 30-34 | 167 | 153 | 139 | 150 | 169 | 154 | 133 | 116 | 102 |
| 35-39 | 127 | 110 | 90 | 101 | 121 | 105 | 84 | 67 | 54 |
| 40-44 | 66 | 53 | 39 | 45 | 56 | 47 | 35 | 26 | 19 |
| 45-49 | 12 | 9 | 5 | 6 | 8 | 7 | 5 | 4 | 3 |
| TFR | 4.1 | 4.0 | 3.8 | 3.8 | 3.8 | 3.4 | 2.9 | 2.5 | 2.2 |

Note that some sub-districts came into being after 1980. In such cases these estimates are hypothetical, and can be thought of as being applicable to the population that eventually settled in that sub-district at the time they were first counted in the census.

| Sowa Pan | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 152 | 135 | 121 | 78 | 37 | 28 | 26 | 24 | 24 |
| 20-24 | 269 | 225 | 188 | 174 | 165 | 146 | 127 | 111 | 104 |
| 25-29 | 295 | 244 | 199 | 212 | 229 | 207 | 180 | 156 | 147 |
| 30-34 | 269 | 225 | 187 | 181 | 178 | 157 | 134 | 114 | 106 |
| 35-39 | 216 | 186 | 160 | 126 | 95 | 77 | 63 | 52 | 46 |
| 40-44 | 120 | 108 | 98 | 63 | 31 | 21 | 17 | 13 | 11 |
| 45-49 | 25 | 24 | 24 | 14 | 3 | 1 | 1 | 1 | 1 |
| TFR | 6.7 | 5.7 | 4.9 | 4.2 | 3.7 | 3.2 | 2.7 | 2.4 | 2.2 |

| Southern | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 166 | 153 | 141 | 125 | 108 | 88 | 70 | 56 | 44 |
| 20-24 | 294 | 266 | 239 | 214 | 189 | 167 | 147 | 129 | 114 |
| 25-29 | 322 | 292 | 263 | 233 | 203 | 186 | 171 | 157 | 144 |
| 30-34 | 294 | 271 | 250 | 214 | 179 | 157 | 138 | 122 | 108 |
| 35-39 | 236 | 223 | 212 | 175 | 139 | 112 | 90 | 72 | 58 |
| 40-44 | 131 | 128 | 127 | 101 | 74 | 56 | 42 | 31 | 22 |
| 45-49 | 27 | 28 | 30 | 22 | 14 | 10 | 8 | 5 | 4 |
| TFR | 7.3 | 6.8 | 6.3 | 5.4 | 4.5 | 3.9 | 3.3 | 2.9 | 2.5 |

| South-East | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 113 | 104 | 95 | 79 | 64 | 52 | 43 | 36 | 34 |
| 20-24 | 202 | 192 | 185 | 163 | 141 | 124 | 109 | 98 | 100 |
| 25-29 | 221 | 208 | 197 | 180 | 163 | 149 | 136 | 125 | 132 |
| 30-34 | 201 | 180 | 162 | 152 | 143 | 127 | 111 | 98 | 99 |
| 35-39 | 159 | 136 | 113 | 107 | 105 | 88 | 71 | 57 | 53 |
| 40-44 | 87 | 70 | 53 | 50 | 51 | 41 | 31 | 23 | 19 |
| 45-49 | 18 | 13 | 8 | 8 | 8 | 6 | 5 | 4 | 3 |
| TFR | 5.0 | 4.5 | 4.1 | 3.7 | 3.4 | 2.9 | 2.5 | 2.2 | 2.2 |

| Kweneng | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 180 | 175 | 173 | 134 | 95 | 76 | 62 | 50 | 41 |
| 20-24 | 319 | 281 | 246 | 207 | 172 | 152 | 137 | 123 | 110 |
| 25-29 | 350 | 301 | 255 | 223 | 195 | 180 | 168 | 156 | 144 |
| 30-34 | 319 | 281 | 244 | 214 | 186 | 164 | 144 | 126 | 111 |
| 35-39 | 256 | 237 | 220 | 189 | 158 | 127 | 102 | 80 | 63 |
| 40-44 | 142 | 143 | 145 | 120 | 93 | 71 | 53 | 39 | 27 |
| 45-49 | 29 | 35 | 42 | 32 | 21 | 16 | 11 | 8 | 5 |
| TFR | 8.0 | 7.3 | 6.6 | 5.6 | 4.6 | 3.9 | 3.4 | 2.9 | 2.5 |

| Kgatleng | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 140 | 125 | 110 | 99 | 88 | 73 | 58 | 47 | 39 |
| 20-24 | 249 | 231 | 216 | 189 | 162 | 142 | 125 | 110 | 101 |
| 25-29 | 273 | 255 | 240 | 208 | 176 | 160 | 147 | 135 | 129 |
| 30-34 | 249 | 228 | 210 | 182 | 155 | 136 | 120 | 106 | 97 |
| 35-39 | 200 | 177 | 156 | 136 | 118 | 97 | 78 | 63 | 52 |
| 40-44 | 111 | 94 | 78 | 69 | 62 | 49 | 37 | 27 | 20 |
| 45-49 | 23 | 18 | 14 | 12 | 11 | 9 | 7 | 5 | 3 |
| TFR | 6.2 | 5.6 | 5.1 | 4.5 | 3.9 | 3.3 | 2.9 | 2.5 | 2.2 |

| Central | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 155 | 151 | 147 | 126 | 103 | 84 | 68 | 55 | 44 |
| 20-24 | 276 | 261 | 247 | 223 | 199 | 176 | 155 | 137 | 120 |
| 25-29 | 302 | 282 | 262 | 241 | 220 | 203 | 186 | 170 | 155 |
| 30-34 | 276 | 254 | 234 | 214 | 195 | 173 | 152 | 133 | 117 |
| 35-39 | 221 | 202 | 185 | 166 | 148 | 122 | 98 | 79 | 63 |
| 40-44 | 122 | 112 | 101 | 88 | 76 | 59 | 45 | 33 | 24 |
| 45-49 | 25 | 23 | 20 | 17 | 14 | 10 | 8 | 6 | 4 |
| TFR | 6.9 | 6.4 | 6.0 | 5.4 | 4.8 | 4.1 | 3.6 | 3.1 | 2.6 |

Note that some sub-districts came into being after 1980. In such cases these estimates are hypothetical, and can be thought of as being applicable to the population that eventually settled in that sub-district at the time they were first counted in the census.

| North-East | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 148 | 155 | 164 | 140 | 112 | 90 | 72 | 57 | 45 |
| 20-24 | 262 | 255 | 249 | 223 | 194 | 170 | 150 | 132 | 116 |
| 25-29 | 288 | 272 | 255 | 232 | 206 | 190 | 175 | 161 | 147 |
| 30-34 | 263 | 247 | 231 | 207 | 181 | 160 | 142 | 125 | 111 |
| 35-39 | 211 | 200 | 189 | 165 | 140 | 115 | 93 | 74 | 59 |
| 40-44 | 117 | 113 | 110 | 93 | 75 | 58 | 43 | 32 | 23 |
| 45-49 | 24 | 24 | 25 | 20 | 14 | 11 | 8 | 6 | 4 |
| TFR | 6.6 | 6.3 | 6.1 | 5.4 | 4.6 | 4.0 | 3.4 | 2.9 | 2.5 |

| North-West | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 156 | 153 | 150 | 135 | 117 | 96 | 78 | 62 | 50 |
| 20-24 | 277 | 253 | 231 | 206 | 181 | 165 | 150 | 137 | 124 |
| 25-29 | 304 | 273 | 243 | 220 | 199 | 190 | 182 | 172 | 161 |
| 30-34 | 277 | 251 | 227 | 212 | 199 | 180 | 160 | 142 | 126 |
| 35-39 | 222 | 207 | 193 | 188 | 186 | 155 | 123 | 97 | 76 |
| 40-44 | 123 | 120 | 117 | 121 | 126 | 101 | 75 | 54 | 38 |
| 45-49 | 25 | 27 | 29 | 33 | 37 | 30 | 22 | 15 | 10 |
| TFR | 6.9 | 6.4 | 6.0 | 5.6 | 5.2 | 4.6 | 3.9 | 3.4 | 2.9 |

| Ghanzi | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 133 | 147 | 163 | 147 | 123 | 100 | 79 | 63 | 50 |
| 20-24 | 235 | 229 | 224 | 207 | 190 | 170 | 152 | 136 | 121 |
| 25-29 | 258 | 235 | 213 | 204 | 199 | 190 | 178 | 166 | 154 |
| 30-34 | 235 | 209 | 183 | 181 | 185 | 169 | 150 | 133 | 118 |
| 35-39 | 189 | 166 | 143 | 147 | 156 | 133 | 106 | 85 | 67 |
| 40-44 | 105 | 92 | 80 | 85 | 94 | 77 | 57 | 42 | 29 |
| 45-49 | 21 | 19 | 17 | 19 | 23 | 18 | 13 | 10 | 6 |
| TFR | 5.9 | 5.5 | 5.1 | 4.9 | 4.8 | 4.3 | 3.7 | 3.2 | 2.7 |

| Kgalagadi | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| 15-19 | 125 | 122 | 120 | 113 | 106 | 88 | 70 | 56 | 44 |
| 20-24 | 221 | 226 | 234 | 216 | 192 | 169 | 148 | 129 | 113 |
| 25-29 | 242 | 245 | 250 | 229 | 203 | 186 | 171 | 156 | 143 |
| 30-34 | 221 | 213 | 206 | 190 | 172 | 153 | 135 | 120 | 106 |
| 35-39 | 177 | 161 | 143 | 133 | 126 | 105 | 85 | 69 | 55 |
| 40-44 | 98 | 83 | 66 | 63 | 62 | 50 | 38 | 28 | 20 |
| 45-49 | 20 | 15 | 10 | 10 | 11 | 9 | 6 | 5 | 3 |
| TFR | 5.5 | 5.3 | 5.1 | 4.8 | 4.4 | 3.8 | 3.3 | 2.8 | 2.4 |

Note that some sub-districts came into being after 1980. In such cases these estimates are hypothetical, and can be thought of as being applicable to the population that eventually settled in that sub-district at the time they were first counted in the census.

# APPENDIX 5
# BASIS FOR MORTALITY ESTIMATION

## A5.1 Introduction

Estimating mortality rates in Africa is at the best of times a haphazard enterprise, since few countries have reliable, let alone complete, vital registration systems, and estimates usually have to be derived either through the use of indirect questions (such as mothers reporting on the number of births and deaths of their children, or children reporting on the survival of their parents), or from deaths reported by households. Estimating non-AIDS mortality in an era of HIV/AIDS is an order of magnitude more difficult, with the results being that much more uncertain.

Child and adult mortality will be dealt with separately since the data available, approaches and trends in the rates differ. After that the rates are combined to produce a single life table for each of the years and turn our attention to estimating the rates for each of the census districts.

## A5.2 Infant and childhood mortality

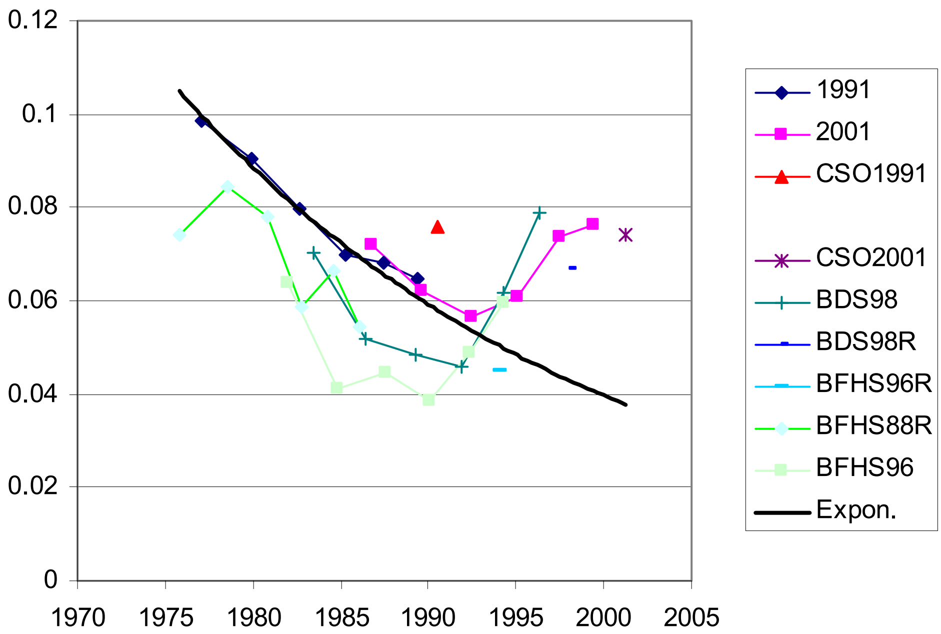
The primary data on infant and child mortality are the answers to the so-called Brass questions of mothers asking them to report on how many children they have borne and how many are still alive. Together with the age of the mother and some modelled relationships and assumptions (described in various texts, e.g. Brass (1975); United Nations (1983)) one is able to translate these numbers into probabilities of survival of children from birth to specific average ages and hence into infant and child mortality rates. Inspection of these data from various sources, as is shown for the under-five mortality rates in Figure A6.1[*], lead to two conclusions about the sources of data, namely that responses from the two censuses (1991 and 2001) are remarkably consistent until the early 1990s, and that, given that consistency, the responses from the other surveys produce estimates that not only are inconsistent with one another, but are somewhat lower than those from the census. On the basis of this comparison it was decided to base our estimates on the census data alone.

Unfortunately the Brass 'children ever borne – children surviving' technique produces results which significantly biased downwards in an AIDS epidemic (Ward and Zaba (unpublished) and Zaba, Marston and Floyd (2003)) and thus cannot be relied upon to produce estimates of child mortality in Botswana after about the early 1990s.

[*] Estimates based on the responses of women in the 15-19 age group have been excluded since the mortality of their children is likely to be higher than that of the rest of the women.

Thus the projected non-AIDS mortality rates were based on an exponential extrapolation of the trend in the estimates derived from the 1991 census adjusted slightly in the most recent years to remove the expected influence of HIV on the mortality rates. This curve is shown in Figure A5.1. This process was repeated for the infant mortality rates, both curves fitting the data extremely closely.

**Figure A5.1 Under-five mortality rates from various surveys ('R' being reported estimates)**




In order to produce sex-specific rates the average ratio of the sex-specific rates to the overall rates for each sex for the first three points in time (in order to avoid the impact of HIV/AIDS on this ratio) derived from the 2001 census data* was applied to the rates estimated from the exponential curve fitted as described above.

Rates at individual ages from 0 to 4 were derived by assuming that the force of mortality followed a hyperbolic curve with respect to age over this age range as determined by these infant and under-five mortality rates.

### A5.3 Non-child mortality

Deriving adult mortality rates was a complex process that involved the following stages:

1. Rates for the year prior to each census (1981, 1991 and 2001) and for each intercensal period (1981-1991 and 1991-2001) were derived by applying the Generalised Growth Balance (Hill 1987) and Synthetic Extinct Generations (Bennett and Horiuchi 1981,

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* This was necessary since the 1991 census did not ask about the sex of the child.

1984) methods in combination as suggested by Hill and Choi (2004), to the deaths reported by households in each census and census populations[*], to estimate the extent of completeness of reporting of the deaths. Rates of mortality were then calculated after correcting for incompleteness in reporting of deaths.

2. These rates were then compared against estimates derived by others (see Figure A5.2). Inspection suggested that with the exception of the rates for males in 1981, the rates thus produced could be considered to be reasonable. Because of the implausible rates for males in 1981 it was decided not to use the rates produced for 1981 for either sex, but instead to use the rates produced by Tumkaya as part of the 1981 census analytical report[†].

3. In order to derive estimates of non-AIDS mortality one needs to remove from these rates the impact of AIDS. Since we have no way of knowing exactly what proportion of these deaths were due to HIV/AIDS the best we can do is to make use of the AIDS mortality rates produced by the model. This approach is limited by the extent to which the empirical data capture the full extent of the AIDS mortality and the accuracy to which the model reflects the level and pattern by age, and for this reason we confined ourselves to estimating the rates non-AIDS mortality for years up to and including 1996. Thus the non-AIDS mortality rates were derived by estimating the non-AIDS 'associate single decrement rates' by removing the impact of HIV/AIDS as estimated from the ASSA model and then graduating using Brass's Relational model (Brass 1968). The standard tables used were those suggested by Tumkaya (in order to produce consistent trends over time over the whole age range), namely the West life table (Coale, Demeny and Vaughan 1983) for males and Brass's African Standard Life Table (Brass 1968) for females[‡].

4. The resultant non-AIDS mortality rates were expanded to rates at individual ages, from age seven upwards, using Beers' six-parameter interpolation (Shryock and Siegel 1976).

5. Rates for individual years were obtained by first determining the exponential trend in the excess of the above rates over the ultimate rates assumed in the ASSA model at each age for each sex, assuming that the rate in 1981 was as estimated above and that the rates for the intecensal periods applied in the years 1986 and 1996 respectively.

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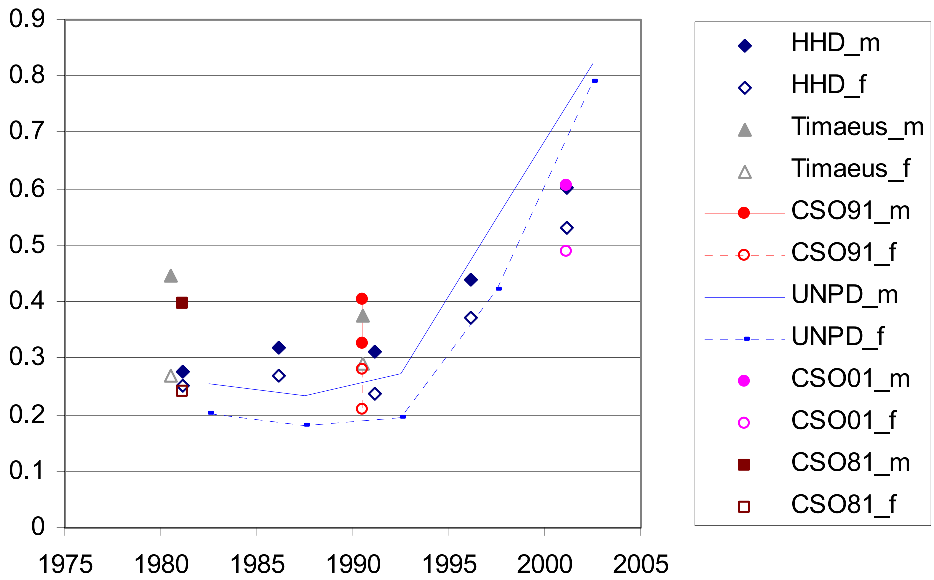
[*] Corrected for unspecified age as published by Bulatao (CSO 2005)

[†] Although the method used to produce these rates is questionable, the level of the adult mortality rates thus produced is consistent with those of Timæus (1998)

[‡] The level and shape of these fits were adjusted to ensure that the resultant ${}_{45}q_{15}$ and $m_{80}$ were the same as those of the empirical data (after removing the impact of HIV/AIDS).

These trends were then smoothed (to avoid discontinuities in the rates by age projected in future years) and converted into 'reduction factors' to be used to derive rates for each year from those in 1981.

**Figure A5.2 Adult mortality (45q15)**




(HHD are rates derived as part of this research, 'm' for male, 'f' for female)

## A5.4 Full life tables and projected non-AIDS mortality rates

The rates at all ages were produced by blending the infant and child mortality rates with the adult mortality rates from ages 10 and upwards.

Inspection of the 'reduction factors' implied by the fit of the empirical data up to 1996 suggested that if these were used to project the rates into future years then male mortality would eventually fall below the female mortality. Thus it was decided to project both rates using the average of the male and female reduction factors for 1981-1996.

## A5.5 District non-AIDS mortality rates

### A5.5.1 Introduction

Full life tables were produced by first estimating childhood mortality ($_5q_0$) and adult mortality ($_{45}q_{15}$) for each district and then using these and Brass's relational model with the national life table as standard to generate full life tables for each district. The process of estimating the rates and the results are presented in more detail below.

### A5.5.2 Child mortality

Under-five mortality rates were estimated for both sexes combined for each district as reported by women aged 35 and over[*] (i.e. in the period 1986 to 1993) in the 2001 census data, using the same method and standard table as used to produce the national rates. These rates were then averaged and compared to the average of the national rates for these women. From this a scaling factor was derived which as assumed to apply to the non-AIDS mortality rates from 1980 to 1996 for both boys and girls.

Although the range in estimates was greater than expected (from about 50% to 150% of the national rates this did not seem to be a function, particularly, of the sample size and so it was decided to accept these estimates except for Ghanzi and the Kgalagadi Game Reserve for which estimates based on combined data were derived.

### A5.5.3 Adult mortality

Since adult mortality is based on the deaths reported by households to have occurred in the previous year or so, the only data not to be significantly influenced by HIV/AIDS was that from the 1991 census. Thus these data were used to produce estimates of adult mortality (${}_{45}q_{15}$) with the intention of then estimating scaling factors from a comparison of the district-specific rates with those of the country as a whole (on the assumption that there was no reason to suppose households in one district reported deaths better than households in any other district). Unfortunately the sample sizes in some districts were too small to produce reliable estimates and rates for these districts had to be approximated as follows.

First, the rates for males and females for each district were averaged and the male and female rates were regressed on these average rates. Then the obvious outliers (either because the average mortality rate was too high or low or the female mortality was substantially higher than the male mortality) were excluded and the regression coefficients applied to the average mortality rates, where these were deemed to be reasonable. Where the average mortality rates were not deemed to be reasonable the mortality rates were either set to those of surrounding sub-districts or to the national average, where no better estimate could be found.

Finally scaling factors were derived as the ratio of these rates to those for the country as a whole and used to scale the national non-HIV adult mortality for each sub-district.

[*] These older women were chosen to limit the impact of HIV/AIDS on the results.

# APPENDIX 6
# BASE POPULATION AND MIGRATION

### A6.1 Introduction

This appendix describes the method of estimation of the number of migrants and hence of the base population.

### A6.2 Migration

For most countries, international migration is a relatively small component of the national demographic balancing equation. This is not the case in Botswana which has experienced non-trivial flows over the 20 years from 1981 to 2001. In addition to this it is likely that, in common with South Africa, the country will have experienced its share of hidden migration from Zimbabwe, particularly in recent years. Unfortunately, as is the case with most countries, particularly developing countries, it is extremely difficult to document accurately these flows of migrants.

For this project we adopted a two stage approach. The first stage was to estimate the flow of immigrants net of emigrants by sex and age over each of the intercensal periods by making use of the difference in the 'stock' of each of the foreign-born population resident in Botswana, and of the Batswana population resident outside the country. The second stage was, as part of the reconciliation of the census populations, to check if there was an excess in the 2001 census that could be reasonably explained by hidden migration – if so then the numbers of immigrants could be increased by this shortfall.

### A6.3 Census implied migration

The number of surviving immigrants less the number emigrants in five-year age groups up to the open interval (75 and over) as at the end of the intercensal period were derived as the difference between the number foreign-born less the number of absentee Batswana at that age in the second census, less the same figure ten years younger in the first census. To these numbers were added back the number that might have been expected to have died before the second census on the assumption that migration took place uniformly over the intercensal period. Unfortunately the only record of the 1991 absentee population is what is publicly available from the ACAP website[*], namely totals by five-year age groups for both sexes combined, and total numbers for each sex.

[*] http://www.acap.upenn.edu/frames/Body_PACE.htm

Thus the numbers for this census had to be approximated via apportionment that reproduced the data available from ACAP.

Numbers of migrants at individual ages were derived from these numbers using Beers interpolation (Shryock and Siegel 1976) and then converted to numbers for each of the years on the assumption that migration occurred uniformly over the intercensal period (or birth, if this occurred in this period).

### A6.4 Hidden migration

From the reconciliation of the South African 2001 and 1996 censuses it appears as if most hidden migration to South Africa has taken place in the 20-29 year age band. Although there was a shortfall between the 2001 census and the population projected from the census in 1981 it occurred at ages over 30 and in the 35-39 age group appears to reflect a shortfall in the 1981 census. Thus it was decided to make no adjustment to the migration figures to account for hidden migration.

### A6.5 Base population

In order to allow for the development of the disease from the start of the epidemic the model requires a base population for a year in the early 1980s, 1980 was chosen to facilitate comparability with other models. Thus it was decided to start with the 1981 census back projected one year, which gave rise to the first problem – there are at least four different (some substantially different) tables purporting to be the enumerated population: the 1981 census analytical report (Central Statistics Office (CSO) 1987) and the 2001 census analytical report (Central Statistics Office (CSO) 2004a), both of which are after redistributing those with unknown age to the other ages; the Statistical Yearbook – 2003 (Central Statistics Office (CSO) 2004b) which give the number with unknown ages separately; and the 25% sample as archived by ACAP, which is available for each individual age for both sexes combined and in total for each sex. The last of these sources is the only source giving numbers by individual ages and although the total isn't exactly 25% of the totals for the other sources, and the numbers are particularly different for age groups 75 and above, it was used to derive a distribution of the population by age for each sex. In brief the following approach was adopted:

The estimate of the numbers of males and females combined in each age group were derived by multiplying the ACAP numbers by the ratio of the total population (which was the same for the other three populations).

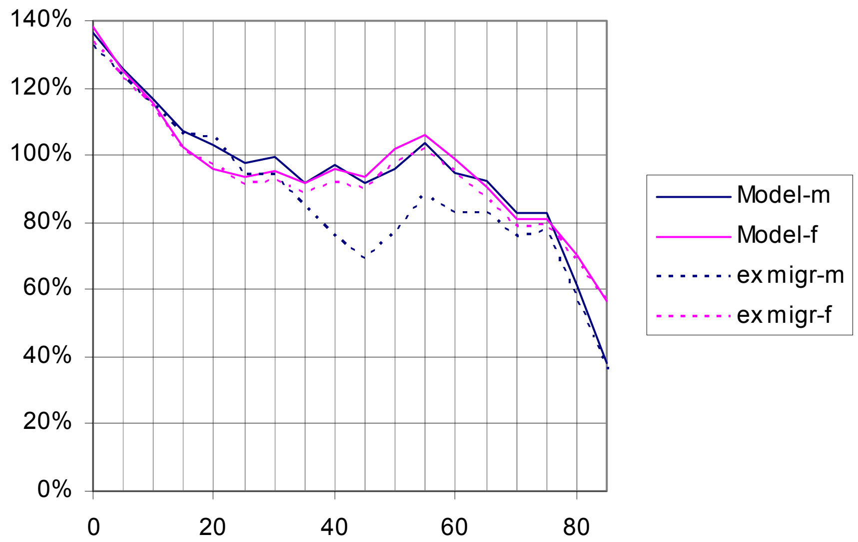
These numbers were then divided into males and females using the five-year ratios from the 2001 analytic report. Those of unknown age were also apportioned in the same ratio as those in this report. Since there were clearly far too many people aged "98" it was decided regard these as also being of unknown age and to redistribute them in proportion to other ages along with the 99s. These numbers were then back projected one year using the mortality and migration estimates in the model, to give the base, or starting, population.

This base population was projected forward (using the estimates of fertility, mortality, migration and HIV/AIDS) and compared to the census populations for both 1991 and 2001.

The base population was then adjusted by a factor determined to be the weighted average of the ratio of the populations of each census at cohort-corresponding ages to that in the 1981 population, using the census numbers in each census as weights. However, for ages in 1980 of 59 and above for males and 69 and above for females the numbers in the subsequent censuses far exceeded the projected number, and it was decided to assume that this was some form of age exaggeration (puzzling though this is), and hence these numbers were not adjusted further.

Figure A6.1 shows the comparison of the projected population against the census in 2001. Three things are apparent from this figure. The first is that census appears to have undercounted the number of children under age 20 for males and 15 for females quite significantly. The second is that there appears to be, as was mentioned above, quite extensive age exaggeration. The third is that migration is significant particularly in the case of males. Of course in terms of numbers the difference at the young ages swamps all other differences.

**Figure A6.1 Ratio of the projected population to the census population in 2001**




(Dotted lines represent the ratio ignoring migration; m – male, and f – female)

### A6.6 Sub-districts

The base populations and migration numbers for each of the census sub-districts were determined in several stages. The first stage was to use the national model created using the national base population, fertility, mortality, migration, epidemiological and intervention assumptions. The second stage was to derive estimates of the population by age and sex for each district for each year from 1980 to 2020. This was achieved as follows:

For each sex the proportion of males and females in each sub-district was determined from the census. Where the census sub-district population was not reported separately in the census it had to be estimated. In 1991 only Ngwakatse-West was missing and its proportion of the total population was assumed to be the same as in 2001. In 1981 several sub-districts were not in existence or recorded (Sowa-Pan, Ngwakatse-West, Kweneng-East and West) and these proportions had to be estimated similarly by setting the smallest to the proportions from subsequent censuses and reducing the proportion of the 1981 sub-district in which these populations were assumed to be included. As the proportions are generally quite small, and as process is self-correcting over time, these approximations are of little consequence.

The sub-district proportions of the population for the years between the censuses were derived by exponential interpolation. The proportions for 1980 were derived by extrapolation of the trend in proportions between 1981 and 1991. Proportions beyond the 2001 census were determined by extrapolation of the trend in changing proportions between 1991 and 2001 assuming that the rate of change in the proportions trended to zero over the following 60 years. For all years the proportions were scaled to ensure they summed to 100%. The projected proportions were then inspected for reasonableness and one, Barolong, appeared to be growing unreasonably quickly and so its projected growth rate was reduced by 2.5% per annum.

Application of the sub-district proportions to the projected national population for each sex thus provides the total number of males and females in each sub-district and each year. These were then distributed to individual ages by deriving, for each sex and year, estimates of the proportions of the population by age. The proportions by age were derived by interpolating and extrapolating the distributions by five-year age groups in the 1991 and 2001 censuses. Proportions at individual ages were derived from these quinquennial proportions using Beers interpolation, and these proportions were used to derive a starting populations for each sub-district which were then used in contingency tables to produce, for each year and each sex, populations by age such that the sum of the sub-districts by age was equal to the national population in that age, and the sum of all ages in a sub-district equalled the total population for that sub-district.

The third stage was to produce prototype models for each of the sub-districts using the national epidemiological and intervention assumptions but district demographic and prevalence assumptions and the base population derived as part of the second stage for 1980. Migration was set to zero. Each model was then calibrated to reproduce as reasonably as possible* the observed antenatal prevalence rates for the particular sub-district.

The fourth stage was to estimate for each sub-district the number of migrants by sex and age for each year. This was achieved by using the sub-district models to project the population one year later assuming no migration for that year and then differencing these numbers from those derived in the second stage. These migrants were then added to the model and the population projected forward to the next year, etc. As a check the sum of the sub-district migrants must be the same as the national net number of migrants.

The final stage was to incorporate sub-district intervention assumptions and to refine the calibration for each district allowing for this and migrants. Finally, the calibration of the national model was refined to ensure that it produced as close a fit to the sum of the district models as possible.

* For a number of sub-districts the observed antenatal results did not conform to a clear pattern making calibration crude at best.

# APPENDIX 7
# PREVALENCE DATA

## A7.1 Introduction

Data on the prevalence of HIV are the single most important indicator of the extent of the epidemic in a population. For the purposes of modelling the demographic impact of the epidemic in Botswana there are two principal sources of prevalence data. The first is the national survey of selected public antenatal care clinics which has been carried out virtually every year since the early 1990s and covering most of the census sub-districts from 2001 (Ministry of Health 2005; National AIDS Coordinating Agency (NACA) 2001, 2002, 2003). The second is the first household prevalence survey (BAIS II) carried out in 2004 (National AIDS Coordinating Agency (NACA), CSO and Other Development Partners 2005).

Unfortunately in practice survey data on prevalence are not without problems, and one needs to take these into account when calibrating the model to reproduce the empirical data. Thus it is necessary to interrogate the data, which is the purpose of this appendix.

## A7.2 Potential problems with the data

The antenatal survey data are subject to the following potential problems:

- The sites and the number tested at each site are not determined on a basis that ensures that the results will be proportionally representative of the country. However, the survey now covers enough sites for a weighted average of the prevalence of the sites to be able to produce a reasonable estimate of the antenatal prevalence of the population of the country as a whole, and its main sub-populations.
- The results could be a biased estimate of the prevalence of women attending antenatal clinics due to the fact that not every pregnant woman attends a public antenatal care clinic during pregnancy. However, this is not likely to be a significant bias since a high proportion of Batswana women attends antenatal clinics (nearly 95% of births occurred in an antenatal clinic since 2000 according to the BAIS II survey).
- The results are biased estimates of the prevalence of all women aged 15-49 since only pregnant (and by definition, sexually active) women are tested. At the younger ages (particularly below age 20) the HIV prevalence estimates can be expected to be much higher than the true prevalence in all women (many of whom would not yet be sexually active). At the older ages the bias might operate in the opposite direction, since women infected with HIV may well be less likely to bear children and hence be part of the survey sample.
- The antenatal sub-districts are not all exactly the same as the census sub-districts.

The household prevalence data are subject to the following potential problems:

- The major problem with such surveys is what is known as the 'non-response' bias. Part of this arises because the survey is not of all people but confined to those who live in households, but as virtually everyone in Botswana lives in households this is unlikely to be a significant source of bias. By far the largest part of the non-response will be due to people not participating in the survey out of choice, and since this decision may well be linked to the risk of being HIV-positive it could, in surveys with response rates as low as was the case in Botswana (61%) lead to significant bias in the estimates produced by such surveys.
- The reliability of testing saliva for the virus in an African setting (and particularly when applied to children) is unknown.

The two surveys also have the following potential problems in common:

- The samples are small and thus any estimates will be subject to a degree of statistical uncertainty.
- The lack of confirmatory testing of all surveys except the most recent antenatal survey means that the results of all except this survey will be quite uncertain but possibly biased upward[*].
- Neither survey covers all the census sub-districts, although the household survey is reasonably complete.
- The age distributions of the samples (and in the case of the BAIS sample, the weighted population) do not correspond with those of the census.

### A7.3 Prevalence data

Table A7.1 presents the prevalence data from the antenatal surveys by survey district over the years while Table A7.2 presents the results in census sub-districts of the household prevalence survey. The antenatal prevalence results are also presented visually in Figure A7.1. The prevalence of women attending antenatal clinics range from around 20% in the Gantsi district to around 50% in the Selebi/Phikwe district, with national prevalence of around 35%. There doesn't appear to be much difference between the prevalence of HIV in urban and rural sub-districts. There is some evidence that prevalence may have peaked, with only six of the 22 sub-districts showing higher prevalence in 2005 than in 2003, however, given the lack of confirmatory testing in the pre-2005 surveys it is too early to draw firm conclusions.

[*] The sensitivity and specificity estimates reported by manufacturers are usually based on studies conducted in the developed world. False positive reactions tend to be more common in the African context (van Kerkhoven et al, 1991). The Vironostika HIV Uni-form II (the ELISA used in the BAIS II survey) has performed vary variably in African studies, with some studies reporting specificities of 99.5% (Nkengasong et al, 1999) and 99.7% (van Rensberg et al, 1996), and other studies reporting values of less than 90% (Meda et al, 1999; Louis et al, 1999). Studies in Africa have found specificities of the Murex 1.2 test (used in the antenatal survey) to range from 100% (Nkengasong et al, 1999) to 96.5% (Meda et al, 1999). On balance we have assumed a specificity of 98%, which seems to reconcile the experience in South Africa.

**Table A7.1 Observed antenatal prevalence by district and nationally (%)**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bobirwa | | | | | | | | | | 44.0 | 45.3 | 49.3 | **39.6** | 29.8 |
| Boteti | | | | | | | | | | 36.7 | 35.6 | 31.9 | **33.7** | 35.4 |
| Chobe | | 18.3 | | 37.9 | **38.4** | 38.8 | **44.8** | 50.8 | **45.0** | 39.1 | 38.4 | 47.0 | **38.0** | 28.9 |
| Francistown | 23.7 | 34.2 | 29.7 | 39.6 | 43.1 | 42.9 | 43.0 | 42.7 | 40.4 | 44.8 | 41.5 | 45.8 | **44.1** | 42.3 |
| Gaborone | 14.9 | 19.2 | 27.8 | 28.7 | 31.4 | 34.0 | 39.1 | 37.1 | 36.4 | 39.3 | 39.0 | 44.8 | **39.5** | 34.2 |
| Gantsi | | 9.5 | | 18.9 | **20.0** | **21.2** | 22.3 | **22.1** | **22.0** | 21.8 | 18.8 | **19.5** | **20.2** | 20.9 |
| Goodhope | | | | | | | | | | 33.1 | 26.3 | 40.9 | **30.9** | 20.8 |
| Hukuntsi | | | | | | | | | | 23.3 | 40.0 | 28.4 | **28.9** | 29.4 |
| Kgalagadi | | | | | | | | 21.8 | **25.2** | 28.5 | 28.3 | 28.9 | **27.6** | 26.2 |
| Kgatleng | | | | | | 31.1 | **30.3** | 29.5 | **27.2** | 24.9 | 30.9 | 30.6 | **30.4** | 30.1 |
| Kweneng East | | 13.7 | | 18.9 | **25.0** | **31.1** | 37.2 | 33.8 | 30.4 | 29.6 | 29.2 | 32.1 | **31.8** | 31.5 |
| Kweneng West | | | | | | | | | | 25.3 | 28.7 | 27.0 | **27.0** | 27.0 |
| Lobatse | | 17.8 | | 37.9 | **35.8** | 33.7 | **32.5** | 31.3 | **31.0** | 30.6 | 34.6 | 32.4 | **30.7** | 29.0 |
| Mahalapye | | | | | | 28.2 | **30.1** | 32.0 | **32.0** | 31.9 | 39.8 | 37.4 | **36.8** | 36.2 |
| Ngami/North West | | | 19.4 | | 33.1 | **33.3** | 33.5 | | | 35.8 | 40.7 | 38.4 | **32.9** | 27.3 |
| North East | | | | | | | | | | 39.9 | 38.6 | 40.4 | **37.7** | 34.9 |
| Okavango | | | | | | | | | | 40.6 | 34.2 | 32.7 | **31.0** | 29.2 |
| Selebi/Phikwe | | | 27.0 | | 33.1 | **41.5** | 49.9 | **50.1** | 50.3 | 50.0 | 48.1 | 52.2 | **49.4** | 46.5 |
| Serowe/ Palapye | | 19.9 | | 29.9 | **32.2** | 34.4 | **38.1** | 41.8 | **41.4** | 41.0 | 35.2 | 43.3 | **40.4** | 37.5 |
| South East | | | | | | | | | | 32.3 | 26.5 | 27.9 | **30.0** | 32.1 |
| Southern | | | 16.0 | | 21.8 | **23.3** | 24.7 | **32.7** | 40.7 | 31.5 | 30.5 | 25.7 | **27.0** | 28.2 |
| Tutume | | | 23.1 | | 30.0 | **33.8** | 37.5 | **36.4** | 35.3 | 51.1 | 40.7 | 37.7 | **39.5** | 41.3 |
| Botswana | **15.6** | **19.5** | **21.5** | **29.2** | **29.9** | **32.4** | **34.5** | **33.2** | **33.4** | 36.2 | 35.4 | 37.4 | **35.4** | 33.4 |
| Urban | **17.5** | **19.9** | **25.2** | **28.3** | **30.3** | **32.7** | **36.2** | **36.7** | **36.5** | **35.8** | **35.3** | **37.8** | **36.1** | 34.5 |
| Rural | | **12.9** | **21.6** | **26.2** | **30.3** | **32.3** | **34.8** | **33.5** | **32.7** | **38.3** | **36.3** | **36.4** | **33.8** | 31.1 |
| Botswana** | | **17.6** | **24.0** | **27.6** | **30.3** | **32.6** | **35.8** | **35.7** | **35.2** | **36.6** | **35.6** | **37.4** | **35.4** | 33.4 |
| 15-19 | 16.4 | 21.8 | 20.7 | 32.4 | 27.2 | 28.0 | 28.6 | 21.5 | 22.9 | 24.7 | 21.0 | 22.8 | | |
| 20-24 | 20.5 | 27.1 | 31.5 | 34.8 | 40.9 | 41.4 | 42.8 | 38.7 | 39.4 | 38.7 | 37.4 | 38.6 | | |
| 25-49 | 13.6 | 16.0 | 18.3 | 25.9 | 27.2 | 31.1 | 34.0 | 35.9 | 35.5 | 40.0 | 40.5 | 42.8 | | |
| Botswana*** | 15.6 | 19.5 | 21.5 | 29.2 | 29.9 | 32.4 | 34.5 | 33.2 | 33.4 | 36.2 | 35.4 | 37.4 | | |

* Figures in red and bold interpolated linearly, or derived as weighted averages of the sub-district prevalence rates

** Derived as a weighted average of the weighted average of the prevalence of the urban and rural sites, using the population of women 15-49 as weights

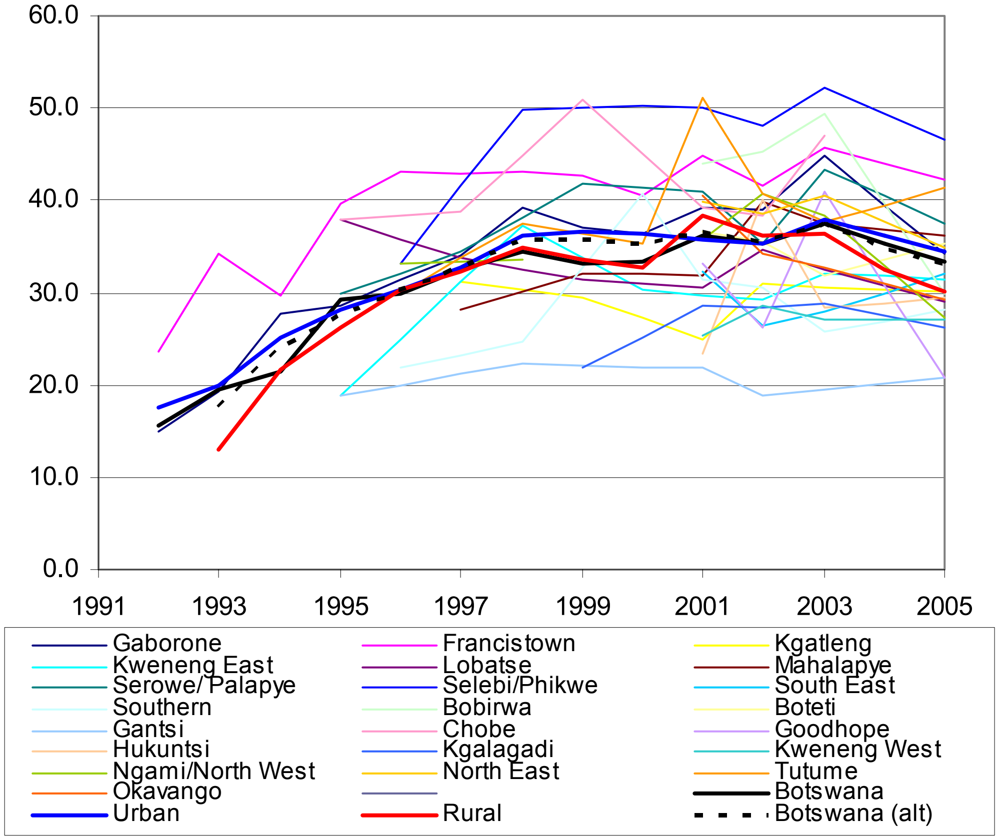
*** Derived as a weighted average of the prevalence of the three age groups

Not unexpectedly, given the biases in the antenatal survey as an indicator of the prevalence of women age 15-49, the prevalence levels from the household survey are on average some 5.5% lower than those from the antenatal survey. However, somewhat unexpectedly the prevalence of HIV in women in the urban sub-districts is around 3% lower than that in the rural sub-districts The contradiction of the relationship of these prevalence rates in the report (National AIDS Coordinating Agency (NACA), CSO and Other Development Partners 2005) is probably due to the finer definition of urban and rural (separating out cities, towns and urban villages from the rest, as opposed to classifying whole sub-districts as either urban or rural).

**Table A7.2 Prevalence of women 15-49 by census sub-district from the BAIS II household survey (2004)**

| | | Urban (u) |
|---|---|---|
| Barolong | 33.7% | |
| Central-Bobonong | 40.4% | |
| Central-Boteti | 23.2% | |
| Central-Mahalapye | 36.6% | u |
| Central-Serowe | 33.8% | u |
| Central-Tutume | 37.9% | |
| Chobe | 51.4% | |
| Francistown | 35.1% | u |
| Gaborone | 25.0% | u |
| Ghanzi | 17.3% | |
| Jwaneng | 22.2% | u |
| Kgalagadi North | 27.8% | |
| Kgalagadi South | 25.6% | |
| Kgatleng | 21.2% | |
| Kweneng East | 22.7% | u |
| Kweneng West | 21.9% | |
| Lobatse | 37.1% | u |
| Ngamiland North | 22.8% | |
| Ngamiland South | 28.4% | |
| Ngwaketse West | 33.3% | |
| Northeast | 38.8% | |
| Orapa | 18.4% | |
| Selebi-Phikwe | 35.9% | u |
| Southeast | 22.8% | u |
| Southern | 18.2% | u |
| Sowa | 29.0% | |
| Total | 29.4% | |

**Figure A7.1 Antenatal prevalence by district and nationally**




## A7.4 Reconciliation of the antenatal and household survey results

In order to compare the figures from the two surveys we need to adjust for all biases that we can. In the case of the household prevalence data the only adjustments made were to reduce the prevalence slightly for 'false positive' testing results (assumed to be 2% of the HIV negative participants), and for each district to weight the testing results by the proportion of women by age in the 2001 census*. On average these adjustments reduce the estimated prevalence from this survey by about 2%.

Deriving an estimate of the prevalence of all women 15-49 from the antenatal survey requires us also to adjust for the false positive results. However, before we do that we have to adjust for the biases by age due to the fact that the survey only measures those who are sexually active and fall pregnant. In order to estimate the extent of this bias we estimate from the BAIS survey for each age group the relationship between the prevalence of pregnant women who attended antenatal clinics to that of all women. Ideally one would wish to confine this comparison to women who attended antenatal clinic over the same period as the antenatal result

* These are the weights used for the antenatal survey results and are surprisingly different from the weights used in the BAIS survey.

are being measured, and as Bulatao pointed out (Central Statistics Office (CSO) 2005) because of the sample size it is better for this period to cover a number of years. We used the same period he chose, namely, pregnancies occurring in the period 2000-2004 (including current pregnancies). However, in order for this prevalence to estimate the prevalence that would have been recorded by the clinics at the time one needs to increase the estimate for fact that the mortality of infected women is higher than that of uninfected women and thus, a retrospective estimate derived from a household survey would underestimate the true prevalence, and for the fact that in actual fact one should be considering the prevalence of a population up to four years older at the time of the survey*. Making these adjustments and weighting using the 2001 census numbers produces an estimate of 35.5%, very similar to the average prevalence measured over the four most recent antenatal surveys (2001, 2002, 2003 and 2004), which is mildly confirmatory of the logic employed.

On the basis that these estimates of prevalence are a reasonable proxy for those of women in the BAIS sample who were sexually active and pregnant we are able, by comparison of these rates with those of all women in each age group, to derive an estimate of the extent of the 'pregnancy bias' (the ratio of the prevalence of all women to that of pregnant women (attending public antenatal clinics). These ratios are shown in Table A7.3.

**Table A7.3 Pregnancy ratio derived from the BAIS II survey**

| Age | Ratio |
|---|---|
| 15-19 | 0.45 |
| 20-24 | 0.72 |
| 25-29 | 1.00 |
| 30-34 | 1.06 |
| 35-39 | 1.27 |
| 40-44 | 1.07 |
| 45-49 | 1.03 |

These ratios were then applied to the antenatal prevalence for 2004 for each district (estimated as an average of the 2003, corrected for false positives, and 2005 survey results). These results produced a weighted average estimate of the prevalence of women aged 15-49 in the population

* The adjustment factor is approximately $(5\overline{p}_x)\Big/\left[p_x\left(S_x(1-\overline{p}_x)+5\overline{p}_x\right)\right]$, where $p_x = {}^{0}_{5}N^{+}_{x}\big/{}^{0}_{5}N_x$,
$\overline{p}_x = \left(\sum_{y=x}^{x+4} {}^{0}_{5}N^{+}_{y}\right)\Big/\left(\sum_{y=x}^{x+4} {}^{0}_{5}N_y\right)$, ${}^{t}_{5}N_x$ = the number of women (positive if "+") aged $x$ to $x$+4 in the middle of the year $t$ prior to the survey. $S_x = \sum_{n=0}^{4} {}_{n}s^{+}_{x}$, and ${}_{n}s_x = {}^{0}_{5}N^{+}_{x+n}\big/{}^{n}_{5}N^{+}_{x}$, with ${}^{0}_{5}N^{+}_{x}$ being derived from the model.

of 32%, some 4.8% higher than the weighted household prevalence corrected for false positive. This 4.8% is thus an estimate of the maximum impact of the other, non-measurable, biases, in particular the non-response bias.

On the assumption that the true result lies somewhere in the range between the two estimates it was decided to estimate it as a weighted average of the two using the size of the samples (2001-2005 for the antenatal results to give weight to the consistency of the level of results over time) as weights. This, applied to each of the sub-districts, produced an estimate of 31.3%, around 2.0% (absolute) above that estimated by the BAIS survey. The prevalence of the rural sub-districts remains higher than that of the urban sub-districts but the difference has narrowed to 2.2%. These results are compared in Table A7.4.

**Table A7.4 Prevalence of women 15-49 derived from the antenatal and household prevalence surveys (2004)**

| | Estimate from antenatal survey | Estimate from household survey | Weighted average | Adjustment to antenatal prevalence |
|---|---|---|---|---|
| Bobirwa | 35.8% | 40.0% | 36.1% | 101% |
| Boteti | 31.4% | 22.0% | 30.8% | 98% |
| Chobe | 38.7% | 44.6% | 40.0% | 103% |
| Francistown | 40.4% | 37.0% | 40.1% | 99% |
| Gaborone | 35.7% | 23.8% | 33.5% | 94% |
| Gantsi | 25.5% | 15.5% | 24.4% | 96% |
| Goodhope | 23.9% | 25.9% | 24.2% | 101% |
| Hukuntsi | 28.6% | 17.9% | 24.8% | 87% |
| Jwaneng | 28.1% | 14.0% | 25.5% | 91% |
| Kgalagadi | 24.4% | 24.2% | 24.4% | 100% |
| Kgatleng | 27.2% | 17.9% | 24.8% | 91% |
| Kweneng East | 28.0% | 21.0% | 26.8% | 96% |
| Kweneng West | 25.6% | 18.9% | 25.6% | 100% |
| Lobatse | 27.9% | 35.6% | 28.1% | 101% |
| Mabutsane | | | | |
| Mahalapye | 33.8% | 34.8% | 34.0% | 100% |
| North East | 33.0% | 33.5% | 33.1% | 100% |
| North West | 29.8% | 23.3% | 28.6% | 96% |
| Okavango | 27.8% | 23.3% | 27.5% | 99% |
| Selebi Phikwe | 45.7% | 33.8% | 44.3% | 97% |
| Serowe/Palapye | 37.0% | 31.2% | 36.0% | 97% |
| South East | 27.9% | 19.8% | 26.8% | 96% |
| Southern | 24.5% | 16.2% | 23.2% | 95% |
| Tutume | 35.8% | 35.8% | 35.8% | 100% |
| Total | 32.0% | 27.2% | 31.3% | 98% |

In order to ensure that the antenatal prevalence rates are consistent with this estimate (and those derived for each of the sub-districts corresponding to the antenatal clinic sub-districts) adjustment factors were derived as the ratio of these new estimates to those based on the antenatal prevalence rates. The overall impact is to reduce the prevalence by 1% (in absolute terms) and to reduce the extent of variation between district prevalence rates slightly, as given in Table A7.5.

**Table A7.5 Corrected antenatal prevalence estimates by district and nationally (%)**

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bobirwa | | | | | | | | | | 44.4 | 45.7 | 49.8 | 39.9 | 29.8 |
| Boteti | | | | | | | | | | 36.0 | 34.9 | 31.3 | 33.0 | 35.4 |
| Chobe | | 18.9 | | 39.1 | 39.6 | 40.1 | 46.3 | 52.4 | 46.4 | 40.4 | 39.6 | 48.5 | 39.2 | 28.9 |
| Francistown | 23.5 | 33.9 | 29.5 | 39.3 | 42.7 | 42.5 | 42.6 | 42.3 | 40.1 | 44.4 | 41.2 | 45.4 | 43.7 | 42.3 |
| Gaborone | 14.0 | 18.0 | 26.1 | 27.0 | 29.5 | 31.9 | 36.7 | 34.8 | 34.2 | 36.9 | 36.6 | 42.1 | 37.1 | 34.2 |
| Gantsi | | 9.1 | | 18.1 | 19.2 | 20.3 | 21.4 | 21.2 | 21.0 | 20.9 | 18.0 | 18.7 | 19.4 | 20.9 |
| Goodhope | | | | | | | | | | 33.5 | 26.6 | 41.3 | 31.2 | 20.8 |
| Hukuntsi | | | | | | | | | | 20.2 | 34.7 | 24.6 | 25.1 | 29.4 |
| Kgalagadi | | | | | | | | 21.8 | 25.1 | 28.4 | 28.3 | 28.8 | 27.5 | 26.2 |
| Kgatleng | | | | | | 28.4 | 27.7 | 27.0 | 24.9 | 22.8 | 28.3 | 28.0 | 27.8 | 30.1 |
| Kweneng East | | 13.1 | | 18.1 | 23.9 | 29.7 | 35.6 | 32.3 | 29.1 | 28.3 | 27.9 | 30.7 | 30.4 | 31.5 |
| Kweneng West | | | | | | | | | | 25.3 | 28.7 | 27.0 | 27.0 | 27.0 |
| Lobatse | | 18.0 | | 38.3 | 36.1 | 34.0 | 32.8 | 31.6 | 31.2 | 30.9 | 34.9 | 32.7 | 31.0 | 29.0 |
| Mahalapye | | | | | | 28.3 | 30.2 | 32.1 | 32.1 | 32.0 | 40.0 | 37.6 | 37.0 | 36.2 |
| Ngami/North West | | | 19.4 | | 33.2 | 33.4 | 33.6 | | | 35.9 | 40.8 | 38.5 | 32.9 | 27.3 |
| North East | | | | | | | | | | 38.3 | 37.0 | 38.7 | 36.1 | 34.9 |
| Okavango | | | | | | | | | | 40.2 | 33.8 | 32.4 | 30.6 | 29.2 |
| Selebi/Phikwe | | | 26.2 | | 32.1 | 40.3 | 48.4 | 48.6 | 48.8 | 48.5 | 46.7 | 50.6 | 47.9 | 46.5 |
| Serowe/Palapye | | 19.4 | | 29.1 | 31.3 | 33.5 | 37.1 | 40.7 | 40.3 | 39.9 | 34.3 | 42.2 | 39.3 | 37.5 |
| South East | | | | | | | | | | 31.0 | 25.5 | 26.8 | 28.8 | 32.1 |
| Southern | | | 15.2 | | 20.7 | 22.0 | 23.4 | 31.0 | 38.6 | 29.8 | 28.9 | 24.4 | 25.5 | 28.2 |
| Tutume | | | 23.1 | | 30.0 | 33.8 | 37.5 | 36.4 | 35.3 | 51.1 | 40.7 | 37.7 | 39.5 | 41.3 |
| | | | | | | | | | | | | | | |
| Botswana | 15.6 | 19.5 | 21.5 | 29.2 | 29.9 | 32.4 | 34.5 | 33.2 | 33.4 | 36.2 | 35.4 | 37.4 | 35.4 | 33.4 |
| Urban | 16.8 | 19.2 | 24.1 | 27.3 | 29.2 | 31.5 | 34.8 | 35.3 | 35.1 | 34.5 | 34.0 | 36.4 | 34.8 | 34.5 |
| Rural | | 12.9 | 21.6 | 26.2 | 30.4 | 32.4 | 34.8 | 33.5 | 32.7 | 38.0 | 36.0 | 36.2 | 33.5 | 31.1 |
| Botswana** | | 16.8 | 23.1 | 26.9 | 29.6 | 31.8 | 34.8 | 34.6 | 34.2 | 35.8 | 34.7 | 36.3 | 34.3 | 33.2 |
| | | | | | | | | | | | | | | |
| 15-19 | 16.4 | 21.8 | 20.7 | 32.4 | 27.2 | 28.0 | 28.6 | 21.5 | 22.9 | 24.7 | 21.0 | 22.8 | | |
| 20-24 | 20.5 | 27.1 | 31.5 | 34.8 | 40.9 | 41.4 | 42.8 | 38.7 | 39.4 | 38.7 | 37.4 | 38.6 | | |
| 25-49 | 13.6 | 16.0 | 18.3 | 25.9 | 27.2 | 31.1 | 34.0 | 35.9 | 35.5 | 40.0 | 40.5 | 42.8 | | |
| Botswana*** | 15.6 | 19.5 | 21.5 | 29.2 | 29.9 | 32.4 | 34.5 | 33.2 | 33.4 | 36.2 | 35.4 | 37.4 | | |

** Derived as a weighted average of the weighted average of the prevalence of the urban and rural sites, using the population of women 15-49 as weights

*** Derived as a weighted average of the prevalence of the three age groups

# APPENDIX 8
# INTERVENTIONS

## A8.1 Introduction

The ASSA2003 model allows directly for the effect of interventions (prevention and treatment programmes) on risky sexual behaviours, probabilities of HIV transmission and HIV survival. Five interventions are modelled, namely, information and education campaigns (IEC) and social marketing, syndromic management of sexually transmitted diseases (STDs), voluntary counselling and testing (VCT), mother-to-child transmission prevention (PMTCT) and anti-retroviral treatment (ART).

The purpose of this appendix is to explain the assumptions made about the timing and effect of these HIV/AIDS prevention and treatment programmes. However, only parameters that are different from the default parameters of the ASSA2003 model are explained. The unchanged parameters are assumed to be satisfactory.

## A8.2 Parameters

### A8.2.1 Information and education campaigns (IEC) and social marketing

Information and education campaigns and social marketing programmes are assumed to increase condom usage. This is the main effect and, hence, the assumed rates of phase-in for these programmes have therefore been set in line with trends in the increase in condom usage. These phase-in rates are used in the national and district models.

It is assumed that behavioural change associated with these campaigns started in 1993, although, undoubtedly, condom usage increased from very low levels prior to 1993. This assumption is based on the date when Population Services International (PSI) started promoting 'Lovers Plus' condoms in Botswana. PSI has been recognised as one of the strongest catalysts for "bringing condoms out of the closet and making it socially acceptable in Botswana" (PSI 2006). However, initially, it is assumed that behavioural change is low as information and education campaigns usually require time to before becoming socially acceptable.

Furthermore, in 2003, the Government of Botswana launched an extensive condom distribution and marketing program in a direct response to deficiencies in the supply of condoms and ineffective social marketing strategies (ACHAP 2004). Hence, phase-in rates are assumed to reach a maximum after 2001.

It is further assumed that full introduction of the information and education campaigns and social marketing programmes would result in a 600% increase in condom usage. This assumption is based on the improved condom distribution as the ratio of condoms per sexually active person 15-59 increased from 11 condoms per person in 1997 to 44 condoms per person in 2002 (NACA 2003b).

The rates of condom usage are guided by data from BAIS I and BAIS II, although, the condom usage rates reported in these surveys are incompatible with both the consistently high prevalence levels and the relatively high fertility rates. Hence, the assumed rates of phase-in for the information and education campaigns and social marketing programmes have been set to correspond approximately to 75% of the condom usage rates reported by women in BAIS I.

It is assumed that condom usage with boyfriends and causal partners are representative of the RSK group. Furthermore, it is assumed that condom usage of the PRO group is 1.3 times that of the RSK group. This assumption is based on data from BAIS II. Lastly, condom usage of the STD group is set midway between the PRO and the RSK groups.

#### A8.2.2 Syndromic management of STDs

Improved STD treatment, through syndromic management of STDs, lowers the probability of HIV transmission, because other STDs enhance the risk of HIV transmission when present in either the HIV-negative or HIV-positive partner.

Syndromic management protocols were first introduced into the public health system in Botswana in 1992 (Bailey *et al* (no date)). It is assumed that syndromic management protocols were phased-in linearly over the period 1992-1996, i.e. it is assumed that by the end of 1996 all public health facilities that manage STDs followed the sydromic management approach. This assumption is based on information of the national STD control program which was formulated under the first medium term plan (1992-1996) for STD/AIDS control (Boonstra *et al* 2003). Furthermore, phase-in rates are assumed to reach a maximum after 2000 as under the second medium term plan (1997–2002) for STD control there were increased efforts to integrate STD care services into reproductive and primary care (Boonstra *et al* 2003). These phase-in rates are used in the national and district models.

#### A8.2.3 Voluntary counselling and testing (VCT)

The Tebelopele VCT centres were first introduced in April 2000. These are the primary VCT centres. Initially, these centres were only implemented in a few districts. However, by the end of 2003, these centres were available nationally.

It is assumed that VCT was first introduced in Botswana in 2000 since, before the opening of the Tebelopele VCT centres, there was a critical gap in VCT services in Botswana, with very limited access to HIV testing services and no organization with capacity to provide

VCT on a national scale (BOTUSA 2004). Furthermore, based on district level data from the Tebelopele VCT centres, the initial phase-in rates are set at a low level, but assumed to increase rapidly. In addition, in January 2004, routine HIV testing (RHT) was introduced into all public hospitals.

It is further assumed that, by 2004, access to VCT was close to its maximum level since, by the end of 2003, there was broad coverage of VCT services, with 80% of the population living within a 50 km radius of a HIV-testing centre (BOTUSA 2004).

During 2004, there were approximately 55 000 first time testers at the Tebelopele VCT centres (NACA 2005). In addition, approximately 65 000 individuals were also tested via the routine HIV testing programme (Ministry of Health 2004, Medical News Today 2005). However, it has been found that individuals who autonomously seek HIV counselling and testing, e.g. through the Tebelopele VCT centres, are more likely to modify their sexual behaviour than individuals who are offered HIV testing, e.g. through RHT (Weinhardt *et al* 1999). Thus, the effects of RHT on sexual behaviour are weaker than those of VCT. Hence, the phase-in rates for VCT are set to ensure that the total number of individuals receiving VCT, according to the model, is roughly consistent with the number of first time testers at the Tebelopele VCT centres. For completeness, the number of individuals receiving VCT during the period 2000-2004 are, approximately, 2 000 for 2000, 13 000 for 2001, 23 000 for 2002 and 40 000 for 2003 (NACA 2003a).

The abovementioned number of individuals receiving VCT is used to set the phase-in rates for the national model. For the district models, the phase-in rates are set with reference to the district level data from the Botswana 2003 Second Generation HIV/AIDS Surveillance Report (NACA 2003a). However, as VCT centres have not been implemented within each of the 28 districts, the phase-in rates in the districts without VCT centres are set similar to the adjacent districts. This is reasonable as, by 2004, 80% of the population were living within a 50 km radius of a HIV-testing centre (BOTUSA 2004). However, it is important to note that the phase-in rates are set with reference to, but not necessarily equal to, the district level data. This is done in order to prevent or reduce, as far as possible, an over count of first time testers as individuals utilizing the VCT centres are likely to be residents of adjacent districts.

#### A8.2.4 Mother-to-child transmission prevention (PMTCT)

The national PMTCT programme was introduced in April 1999. This programme has been available in all districts of Botswana since November 2001 (Stegling 2005). Initially, a short course of AZT for both mother and infant was offered. However, in January 2003, Nevirapine was introduced into the PMTCT programme (NACA 2003b).

According to available programme data (NACA 2003a, 2003b, 2004, 2005, Rakgoasi 2005), the proportion of women offered or has access to PMTCT services has increased steadily from 1999. For example, during 1999, only 60% of women attending antenatal clinics were counselled on PMTCT, whilst as at June 2002, 74% of pregnant women had been counselled on PMTCT (NACA 2003b). However, the first estimate is not representative of national coverage as the PMTCT programme has only been available in all districts of Botswana since November 2001. Hence, phase-in rates were initially set at a low level as coverage increased. From 2002, however, a large proportion of women are assumed to have access to PMTCT services and thus phase-in rates increase significantly, until an assumed maximum coverage rate of 90% from 2005 onwards.

The VCT take-up rate, for women who have access to PMTCT services, increased from 40%, at inception of the PMTCT programme (NACA 2003b), to well over 80% during 2004 and 2005 (BOTUSA 2004, NACA 2004, 2005). Thus, the take-up rate has approximately been set at the average take-up rate over the period 2002-2005 and, hence, assumed to be 80%, which corresponds to the estimate of 79%, for 2001, by Rakgoasi (2005).

In addition, the ART take-up rate is assumed to be 65%. According to programme data (NACA 2004, 2005), this take-up rate has been fairly constant since the start of the programme and, similar to the VCT take-up rate, approximately set at the average take-up rate over the period.

### A8.2.5 <u>Anti-retroviral treatment (ART)</u>

Anti-retroviral treatment lowers the probability of HIV transmission as it lowers the concentration of HIV in the body and, hence, renders recipients less infectious.

Anti-retroviral therapy has been available, in the public sector, since January 2002. However, the exact date of commencement in the private sector is unknown. Nevertheless, it is assumed that ART has been privately available since 2000. This assumption is based on the estimated number of individuals receiving treatment through the private sector during 2002.

The phase-in rates for ART are set with reference to the actual number of individuals on treatment, in both the public and private sectors. The number of individuals on treatment over the period 2001-2005 (as at the middle of the year), are, approximately, 3 000 in 2001, 6 000 in 2002, 12000 in 2003, 25 000 in 2004 and 48 000 in 2005 (Ministry of Health 2004, 2005). Furthermore, the ultimate phase-in rate is assumed to be 90% as it will not be possible for everyone to be able to access treatment.

The abovementioned Masa programme data are used to set the phase-in rates for the national model. The phase-in rates for the district models are set similarly with reference to the district level Masa programme data as virtually all districts have access to antiretroviral treatment. However, the phase-in rates are not set to ensure that the model reproduces the district level data as these exclude individuals receiving ART through the private sector. Hence, the model estimates are likely to be higher than the recoded number of individuals receiving ART.

### A8.3 Summary

The phase-in rates assumed in the national model are summarized in Table . These are the major assumptions with regards to the HIV/AIDS prevention and treatment programmes. All these programmes are assumed, as indicated in text, to start off at modest levels and increase over time.

**Table A8.1 Phase-in rates for IEC, Syndromic management of STDs (SM), VCT, PMTCT and ART, respectively, by year from date of inception, per cent**

| | *Date* | *Year 1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *Subsequent* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IEC | 1993 | 5 | 10 | 17 | 26 | 37 | 50 | 65 | 80 | 90 | 95 |
| SM | 1992 | 15 | 30 | 45 | 60 | 75 | 80 | 85 | 90 | 95 | 95 |
| VCT | 2000 | 12 | 35 | 65 | 85 | 95 | 95 | 95 | 95 | 95 | 95 |
| PMTCT | 1999 | 5 | 15 | 30 | 63 | 83 | 88 | 90 | 90 | 90 | 90 |
| ART | 2000 | 10 | 20 | 35 | 65 | 85 | 88 | 90 | 90 | 90 | 90 |

In addition, it is assumed that with full introduction of the information and education campaigns and social marketing programmes, condom usage would increase 600%. Furthermore, it is assumed that the VCT take-up rate and the ART take-up rate, for women who have access to PMTCT services, is 80% and 65% respectively.

# APPENDIX 9
# ANCILLARY TABLES AND OUTPUTS

## A9.1 Projected numbers of HIV+ orphans in Botswana by age and year

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 76 | 71 | 69 | 68 | 68 | 68 | 68 | 67 | 66 | 66 | 65 | 64 | 63 | 63 | 62 | 62 |
| **1** | 224 | 206 | 198 | 195 | 194 | 193 | 192 | 191 | 189 | 187 | 185 | 183 | 181 | 179 | 177 | 176 |
| **2** | 360 | 337 | 318 | 310 | 307 | 305 | 304 | 303 | 300 | 297 | 294 | 291 | 287 | 284 | 282 | 279 |
| **3** | 470 | 457 | 437 | 419 | 412 | 409 | 407 | 405 | 402 | 399 | 394 | 390 | 386 | 382 | 378 | 374 |
| **4** | 578 | 555 | 545 | 528 | 512 | 505 | 501 | 499 | 496 | 492 | 487 | 482 | 476 | 471 | 467 | 462 |
| **5** | 690 | 654 | 631 | 624 | 611 | 596 | 590 | 585 | 581 | 577 | 572 | 566 | 559 | 553 | 548 | 542 |
| **6** | 779 | 761 | 723 | 701 | 697 | 686 | 671 | 664 | 659 | 654 | 648 | 641 | 634 | 627 | 621 | 614 |
| **7** | 857 | 843 | 823 | 785 | 763 | 760 | 750 | 736 | 729 | 722 | 715 | 708 | 701 | 693 | 686 | 678 |
| **8** | 906 | 911 | 896 | 876 | 839 | 817 | 814 | 804 | 790 | 782 | 774 | 766 | 758 | 749 | 741 | 733 |
| **9** | 908 | 946 | 952 | 939 | 920 | 883 | 861 | 856 | 846 | 832 | 822 | 813 | 805 | 796 | 787 | 778 |
| **10** | 854 | 933 | 972 | 980 | 969 | 951 | 915 | 892 | 886 | 875 | 860 | 850 | 840 | 830 | 821 | 811 |
| **11** | 743 | 863 | 943 | 984 | 995 | 986 | 969 | 933 | 909 | 901 | 890 | 875 | 864 | 853 | 843 | 833 |
| **12** | 590 | 739 | 859 | 939 | 982 | 995 | 988 | 973 | 937 | 913 | 903 | 891 | 876 | 864 | 854 | 843 |
| **13** | 422 | 577 | 724 | 842 | 922 | 965 | 980 | 976 | 962 | 927 | 902 | 891 | 878 | 863 | 852 | 841 |
| **14** | 271 | 404 | 553 | 693 | 805 | 879 | 918 | 928 | 913 | 882 | 830 | 784 | 750 | 728 | 713 | 700 |
| **15** | 159 | 259 | 386 | 529 | 663 | 770 | 843 | 883 | 894 | 882 | 854 | 806 | 763 | 731 | 710 | 690 |
| **16** | 86 | 151 | 246 | 367 | 502 | 631 | 734 | 805 | 845 | 857 | 848 | 823 | 779 | 738 | 708 | 680 |
| **17** | 42 | 81 | 143 | 233 | 347 | 476 | 598 | 698 | 766 | 805 | 819 | 812 | 790 | 748 | 711 | 676 |

Note: Orphans refer to maternal orphans under the age of 18

## A9.2 Numbers infected with HIV, by district and year (1980-2021)

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| Barolong | 0 | 0 | 1 | 1 | 3 | 8 | 17 | 35 | 70 | 131 |
| Bobonong | 0 | 0 | 1 | 3 | 7 | 16 | 36 | 79 | 165 | 322 |
| C.Kgalagadi.G.R | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 8 |
| Central-Boteti | 0 | 0 | 1 | 3 | 7 | 17 | 39 | 84 | 168 | 314 |
| Chobe | 0 | 0 | 0 | 1 | 2 | 5 | 11 | 26 | 58 | 124 |
| Francistown | 0 | 4 | 12 | 32 | 79 | 179 | 376 | 730 | 1 323 | 2 254 |
| Gaborone | 0 | 2 | 6 | 17 | 43 | 104 | 241 | 529 | 1 084 | 2 065 |
| Ghanzi | 0 | 0 | 1 | 2 | 4 | 10 | 22 | 46 | 91 | 169 |
| Jwaneng | 0 | 0 | 0 | 0 | 1 | 2 | 5 | 12 | 26 | 55 |
| Kgalagadi-North | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 |
| Kgalagadi-South | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 8 |
| Kgatleng | 0 | 0 | 1 | 3 | 6 | 15 | 34 | 74 | 154 | 302 |
| Kweneng-East | 0 | 1 | 2 | 5 | 13 | 32 | 75 | 169 | 362 | 728 |
| Kweneng-West | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 10 | 21 | 46 |
| Lobatse | 0 | 0 | 2 | 4 | 11 | 25 | 55 | 116 | 228 | 419 |
| Mahalapye | 0 | 1 | 2 | 5 | 11 | 27 | 59 | 128 | 261 | 499 |
| Ngamiland-Delta | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 8 | 16 |
| Ngamiland-East | 0 | 1 | 2 | 5 | 12 | 27 | 60 | 127 | 254 | 473 |
| Ngamiland-West | 0 | 0 | 0 | 1 | 3 | 9 | 22 | 53 | 118 | 245 |
| Ngwaketse-West | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 7 | 16 | 32 |
| North-East | 0 | 1 | 1 | 4 | 9 | 21 | 46 | 96 | 189 | 346 |
| Orapa | 0 | 0 | 0 | 1 | 2 | 5 | 11 | 25 | 53 | 104 |
| Selebi-Phikwe | 0 | 0 | 2 | 4 | 11 | 26 | 59 | 130 | 272 | 537 |
| Serowe-Palapye | 0 | 1 | 4 | 10 | 24 | 57 | 129 | 278 | 565 | 1 073 |
| South-East | 0 | 0 | 0 | 0 | 1 | 2 | 5 | 11 | 24 | 55 |
| Southern | 0 | 1 | 2 | 4 | 9 | 22 | 50 | 109 | 229 | 456 |
| Sowa-Pan | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 9 | 18 | 34 |
| Tutume | 0 | 1 | 2 | 6 | 14 | 32 | 73 | 158 | 325 | 624 |
| *Sum* | *0* | *13* | *42* | *112* | *276* | *646* | *1 439* | *3 046* | *6 093* | *11 445* |
| **NATIONAL** | **0** | **11** | **34** | **91** | **224** | **531** | **1 214** | **2 658** | **5 506** | **10 657** |

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| Barolong | 229 | 374 | 650 | 1 041 | 1 532 | 2 093 | 2 694 | 3 306 | 3 911 | 4 489 |
| Bobonong | 587 | 1 000 | 1 648 | 2 525 | 3 569 | 4 686 | 5 779 | 6 778 | 7 655 | 8 387 |
| C.Kgalagadi.G.R | 15 | 25 | 38 | 55 | 73 | 90 | 104 | 116 | 125 | 132 |
| Central-Boteti | 549 | 903 | 1 418 | 2 066 | 2 784 | 3 509 | 4 192 | 4 804 | 5 335 | 5 771 |
| Chobe | 246 | 457 | 783 | 1 235 | 1 771 | 2 325 | 2 829 | 3 251 | 3 587 | 3 840 |
| Francistown | 3 606 | 5 386 | 7 322 | 9 309 | 11 183 | 12 901 | 14 437 | 15 770 | 16 895 | 17 788 |
| Gaborone | 3 681 | 6 174 | 9 501 | 13 572 | 17 938 | 22 236 | 26 206 | 29 734 | 32 802 | 35 353 |
| Ghanzi | 293 | 476 | 744 | 1 082 | 1 452 | 1 820 | 2 159 | 2 453 | 2 698 | 2 889 |
| Jwaneng | 109 | 203 | 345 | 548 | 806 | 1 098 | 1 393 | 1 665 | 1 899 | 2 089 |
| Kgalagadi-North | 9 | 20 | 43 | 87 | 161 | 276 | 438 | 645 | 884 | 1 132 |
| Kgalagadi-South | 19 | 40 | 85 | 167 | 302 | 506 | 786 | 1 132 | 1 521 | 1 914 |
| Kgatleng | 551 | 941 | 1 541 | 2 350 | 3 307 | 4 327 | 5 323 | 6 235 | 7 038 | 7 708 |
| Kweneng-East | 1 365 | 2 399 | 3 991 | 6 190 | 8 864 | 11 794 | 14 728 | 17 477 | 19 960 | 22 094 |
| Kweneng-West | 95 | 184 | 335 | 570 | 900 | 1 321 | 1 805 | 2 305 | 2 788 | 3 221 |
| Lobatse | 721 | 1 164 | 1 754 | 2 443 | 3 139 | 3 775 | 4 310 | 4 731 | 5 045 | 5 252 |
| Mahalapye | 892 | 1 495 | 2 412 | 3 633 | 5 068 | 6 595 | 8 091 | 9 464 | 10 673 | 11 676 |
| Ngamiland-Delta | 33 | 61 | 105 | 168 | 246 | 333 | 416 | 489 | 546 | 587 |
| Ngamiland-East | 819 | 1 329 | 2 148 | 3 222 | 4 458 | 5 740 | 6 965 | 8 067 | 9 025 | 9 813 |
| Ngamiland-West | 471 | 845 | 1 346 | 1 990 | 2 716 | 3 456 | 4 156 | 4 779 | 5 313 | 5 743 |
| Ngwaketse-West | 62 | 112 | 190 | 300 | 438 | 593 | 748 | 888 | 1 006 | 1 098 |
| North-East | 594 | 960 | 1 481 | 2 123 | 2 822 | 3 518 | 4 169 | 4 748 | 5 244 | 5 643 |
| Orapa | 191 | 328 | 511 | 739 | 984 | 1 218 | 1 422 | 1 585 | 1 709 | 1 791 |
| Selebi-Phikwe | 988 | 1 703 | 2 776 | 4 194 | 5 825 | 7 497 | 9 044 | 10 378 | 11 484 | 12 356 |
| Serowe-Palapye | 1 906 | 3 182 | 5 009 | 7 327 | 9 911 | 12 529 | 14 998 | 17 201 | 19 101 | 20 650 |
| South-East | 119 | 246 | 489 | 897 | 1 517 | 2 377 | 3 447 | 4 629 | 5 811 | 6 882 |
| Southern | 845 | 1 464 | 2 391 | 3 642 | 5 122 | 6 680 | 8 145 | 9 393 | 10 383 | 11 083 |
| Sowa-Pan | 61 | 100 | 156 | 226 | 302 | 375 | 441 | 496 | 541 | 575 |
| Tutume | 1 120 | 1 888 | 3 024 | 4 511 | 6 224 | 8 014 | 9 746 | 11 322 | 12 708 | 13 861 |
| *Sum* | *20 175* | *33 459* | *52 236* | *76 212* | *103 416* | *131 683* | *158 973* | *183 840* | *205 687* | *223 817* |
| **NATIONAL** | **19 250** | **32 642** | **52 222** | **77 670** | **106 641** | **136 451** | **164 690** | **189 938** | **211 753** | **229 618** |

Note: The sum of the districts does not exactly equal the result from the national model due to slightly different models being applied to each district.

## Table A9.2 (cont) Numbers infected with HIV, by district and year (2000-2019)

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| Barolong | 5 015 | 5 490 | 5 880 | 6 238 | 6 583 | 6 932 | 7 330 | 7 805 | 8 367 | 8 998 |
| Bobonong | 8 951 | 9 368 | 9 652 | 9 839 | 9 995 | 10 191 | 10 465 | 10 765 | 11 065 | 11 348 |
| C.Kgalagadi.G.R | 135 | 137 | 137 | 136 | 135 | 135 | 137 | 139 | 141 | 143 |
| Central-Boteti | 6 097 | 6 326 | 6 464 | 6 542 | 6 632 | 6 760 | 6 921 | 7 096 | 7 272 | 7 439 |
| Chobe | 4 010 | 4 111 | 4 151 | 4 148 | 4 130 | 4 130 | 4 171 | 4 234 | 4 309 | 4 387 |
| Francistown | 18 414 | 18 828 | 19 094 | 19 341 | 19 646 | 19 950 | 20 242 | 20 483 | 20 677 | 20 834 |
| Gaborone | 37 319 | 38 783 | 39 903 | 40 934 | 42 070 | 43 207 | 44 340 | 45 369 | 46 302 | 47 157 |
| Ghanzi | 3 019 | 3 098 | 3 133 | 3 141 | 3 154 | 3 192 | 3 260 | 3 336 | 3 412 | 3 488 |
| Jwaneng | 2 231 | 2 331 | 2 405 | 2 470 | 2 542 | 2 614 | 2 686 | 2 751 | 2 809 | 2 862 |
| Kgalagadi-North | 1 364 | 1 565 | 1 734 | 1 876 | 2 011 | 2 144 | 2 277 | 2 402 | 2 516 | 2 621 |
| Kgalagadi-South | 2 269 | 2 568 | 2 812 | 3 013 | 3 202 | 3 390 | 3 579 | 3 755 | 3 916 | 4 061 |
| Kgatleng | 8 218 | 8 591 | 8 842 | 9 018 | 9 165 | 9 329 | 9 566 | 9 843 | 10 128 | 10 404 |
| Kweneng-East | 23 804 | 25 143 | 26 160 | 26 956 | 27 667 | 28 383 | 29 259 | 30 214 | 31 173 | 32 095 |
| Kweneng-West | 3 582 | 3 873 | 4 104 | 4 290 | 4 462 | 4 640 | 4 846 | 5 057 | 5 259 | 5 449 |
| Lobatse | 5 350 | 5 359 | 5 300 | 5 209 | 5 133 | 5 086 | 5 069 | 5 052 | 5 033 | 5 010 |
| Mahalapye | 12 433 | 12 976 | 13 344 | 13 598 | 13 856 | 14 171 | 14 526 | 14 849 | 15 125 | 15 355 |
| Ngamiland-Delta | 614 | 627 | 630 | 625 | 618 | 612 | 608 | 605 | 602 | 600 |
| Ngamiland-East | 10 405 | 10 833 | 11 108 | 11 283 | 11 487 | 11 745 | 12 031 | 12 299 | 12 542 | 12 764 |
| Ngamiland-West | 6 054 | 6 263 | 6 377 | 6 427 | 6 457 | 6 528 | 6 655 | 6 790 | 6 918 | 7 036 |
| Ngwaketse-West | 1 161 | 1 200 | 1 220 | 1 230 | 1 243 | 1 264 | 1 291 | 1 313 | 1 330 | 1 343 |
| North-East | 5 928 | 6 119 | 6 228 | 6 281 | 6 328 | 6 402 | 6 523 | 6 658 | 6 787 | 6 901 |
| Orapa | 1 832 | 1 837 | 1 819 | 1 788 | 1 757 | 1 734 | 1 718 | 1 702 | 1 685 | 1 668 |
| Selebi-Phikwe | 12 985 | 13 414 | 13 671 | 13 815 | 13 943 | 14 119 | 14 368 | 14 631 | 14 889 | 15 138 |
| Serowe-Palapye | 21 794 | 22 601 | 23 125 | 23 470 | 23 875 | 24 394 | 24 970 | 25 498 | 25 962 | 26 361 |
| South-East | 7 767 | 8 463 | 9 001 | 9 406 | 9 738 | 10 044 | 10 376 | 10 700 | 10 997 | 11 263 |
| Southern | 11 473 | 11 613 | 11 605 | 11 496 | 11 395 | 11 352 | 11 351 | 11 330 | 11 280 | 11 205 |
| Sowa-Pan | 597 | 610 | 614 | 615 | 619 | 626 | 633 | 639 | 645 | 651 |
| Tutume | 14 741 | 15 398 | 15 865 | 16 228 | 16 611 | 17 067 | 17 579 | 18 061 | 18 496 | 18 881 |
| *Sum* | *237 563* | *247 523* | *254 376* | *259 412* | *264 454* | *270 138* | *276 778* | *283 379* | *289 636* | *295 461* |
| **NATIONAL** | **243 080** | **252 434** | **258 715** | **263 121** | **267 812** | **273 748** | **280 364** | **286 957** | **293 233** | **299 065** |

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| Barolong | 9 670 | 10 383 | 11 118 | 11 871 | 12 642 | 13 427 | 14 236 | 15 054 | 15 877 | 16 697 |
| Bobonong | 11 611 | 11 863 | 12 096 | 12 312 | 12 515 | 12 708 | 12 897 | 13 076 | 13 242 | 13 394 |
| C.Kgalagadi.G.R | 145 | 147 | 150 | 152 | 155 | 157 | 160 | 163 | 166 | 169 |
| Central-Boteti | 7 596 | 7 751 | 7 897 | 8 037 | 8 170 | 8 303 | 8 441 | 8 575 | 8 704 | 8 828 |
| Chobe | 4 466 | 4 551 | 4 645 | 4 745 | 4 847 | 4 951 | 5 061 | 5 172 | 5 283 | 5 390 |
| Francistown | 20 963 | 21 103 | 21 234 | 21 363 | 21 495 | 21 631 | 21 788 | 21 952 | 22 123 | 22 290 |
| Gaborone | 47 951 | 48 774 | 49 584 | 50 398 | 51 226 | 52 073 | 52 971 | 53 885 | 54 806 | 55 724 |
| Ghanzi | 3 568 | 3 653 | 3 738 | 3 822 | 3 908 | 3 995 | 4 089 | 4 185 | 4 280 | 4 374 |
| Jwaneng | 2 911 | 2 960 | 3 007 | 3 054 | 3 101 | 3 149 | 3 200 | 3 253 | 3 306 | 3 360 |
| Kgalagadi-North | 2 718 | 2 812 | 2 902 | 2 989 | 3 073 | 3 155 | 3 236 | 3 317 | 3 397 | 3 474 |
| Kgalagadi-South | 4 194 | 4 320 | 4 438 | 4 548 | 4 653 | 4 753 | 4 855 | 4 954 | 5 050 | 5 141 |
| Kgatleng | 10 663 | 10 916 | 11 155 | 11 380 | 11 596 | 11 805 | 12 016 | 12 220 | 12 416 | 12 602 |
| Kweneng-East | 32 968 | 33 837 | 34 672 | 35 481 | 36 270 | 37 041 | 37 814 | 38 587 | 39 351 | 40 102 |
| Kweneng-West | 5 626 | 5 802 | 5 971 | 6 136 | 6 298 | 6 461 | 6 628 | 6 795 | 6 963 | 7 128 |
| Lobatse | 4 985 | 4 968 | 4 955 | 4 951 | 4 957 | 4 970 | 4 991 | 5 011 | 5 030 | 5 045 |
| Mahalapye | 15 542 | 15 713 | 15 857 | 15 977 | 16 080 | 16 168 | 16 253 | 16 327 | 16 390 | 16 443 |
| Ngamiland-Delta | 598 | 597 | 597 | 596 | 596 | 597 | 598 | 599 | 600 | 601 |
| Ngamiland-East | 12 968 | 13 176 | 13 407 | 13 648 | 13 894 | 14 143 | 14 405 | 14 665 | 14 920 | 15 168 |
| Ngamiland-West | 7 150 | 7 264 | 7 376 | 7 483 | 7 586 | 7 686 | 7 789 | 7 887 | 7 979 | 8 062 |
| Ngwaketse-West | 1 354 | 1 364 | 1 373 | 1 381 | 1 389 | 1 398 | 1 408 | 1 418 | 1 429 | 1 439 |
| North-East | 7 001 | 7 092 | 7 170 | 7 236 | 7 294 | 7 345 | 7 400 | 7 451 | 7 498 | 7 539 |
| Orapa | 1 654 | 1 645 | 1 639 | 1 636 | 1 634 | 1 633 | 1 634 | 1 634 | 1 634 | 1 633 |
| Selebi-Phikwe | 15 378 | 15 627 | 15 873 | 16 117 | 16 359 | 16 600 | 16 841 | 17 076 | 17 304 | 17 523 |
| Serowe-Palapye | 26 702 | 27 025 | 27 311 | 27 570 | 27 806 | 28 026 | 28 242 | 28 440 | 28 616 | 28 765 |
| South-East | 11 500 | 11 732 | 11 951 | 12 163 | 12 372 | 12 582 | 12 802 | 13 024 | 13 254 | 13 492 |
| Southern | 11 109 | 11 014 | 10 912 | 10 807 | 10 702 | 10 600 | 10 503 | 10 407 | 10 311 | 10 215 |
| Sowa-Pan | 656 | 663 | 670 | 676 | 683 | 691 | 698 | 706 | 713 | 720 |
| Tutume | 19 217 | 19 531 | 19 809 | 20 056 | 20 275 | 20 472 | 20 662 | 20 834 | 20 991 | 21 139 |
| *Sum* | *300 862* | *306 283* | *311 506* | *316 585* | *321 577* | *326 518* | *331 615* | *336 670* | *341 635* | *346 461* |
| **NATIONAL** | **304 491** | **309 613** | **314 538** | **319 362** | **324 153** | **328 948** | **333 772** | **338 614** | **343 422** | **348 119** |

Note: The sum of the districts does not exactly equal the result from the national model due to slightly different models being applied to each district.

## Table A9.2 (cont) Numbers infected with HIV, by district and year (2020-2021)

| | **2020** | **2021** |
|---|---|---|
| Barolong | 17 503 | 18 204 |
| Bobonong | 13 528 | 13 642 |
| C.Kgalagadi.G.R | 172 | 175 |
| Central-Boteti | 8 946 | 9 058 |
| Chobe | 5 494 | 5 591 |
| Francistown | 22 449 | 22 583 |
| Gaborone | 56 626 | 57 463 |
| Ghanzi | 4 468 | 4 560 |
| Jwaneng | 3 413 | 3 460 |
| Kgalagadi-North | 3 549 | 3 623 |
| Kgalagadi-South | 5 227 | 5 311 |
| Kgatleng | 12 777 | 12 953 |
| Kweneng-East | 40 833 | 41 558 |
| Kweneng-West | 7 291 | 7 454 |
| Lobatse | 5 058 | 5 067 |
| Mahalapye | 16 487 | 16 515 |
| Ngamiland-Delta | 602 | 602 |
| Ngamiland-East | 15 408 | 15 640 |
| Ngamiland-West | 8 138 | 8 212 |
| Ngwaketse-West | 1 448 | 1 455 |
| North-East | 7 571 | 7 590 |
| Orapa | 1 630 | 1 622 |
| Selebi-Phikwe | 17 730 | 17 876 |
| Serowe-Palapye | 28 879 | 28 945 |
| South-East | 13 728 | 13 962 |
| Southern | 10 119 | 10 013 |
| Sowa-Pan | 728 | 733 |
| Tutume | 21 269 | 21 362 |
| *Sum* | *351 068* | *355 230* |
| **NATIONAL** | **352 587** | **356 669** |

Note: The sum of the districts does not exactly equal the result from the national model due to slightly different models being applied to each district.

## A9.3 HIV prevalence, by district and year (1980-2021)

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| Barolong | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.5% | 1.0% | 1.8% |
| Bobonong | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.4% | 0.8% | 1.6% |
| C.Kgalagadi.G.R | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.4% | 0.8% | 1.4% |
| Central-Boteti | - | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.3% | 0.6% | 1.2% | 2.2% |
| Chobe | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.4% | 0.8% | 1.7% |
| Francistown | - | 0.0% | 0.1% | 0.1% | 0.3% | 0.7% | 1.3% | 2.4% | 4.0% | 6.4% |
| Gaborone | - | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.4% | 0.7% | 1.4% | 2.5% |
| Ghanzi | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.5% | 0.9% | 1.6% |
| Jwaneng | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.4% | 0.8% |
| Kgalagadi-North | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% |
| Kgalagadi-South | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% |
| Kgatleng | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.3% | 0.7% | 1.3% |
| Kweneng-East | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.3% | 0.7% | 1.3% |
| Kweneng-West | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.4% |
| Lobatse | - | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.4% | 0.8% | 1.6% | 2.8% |
| Mahalapye | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.4% | 0.7% | 1.3% |
| Ngamiland-Delta | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.3% | 0.6% | 1.1% |
| Ngamiland-East | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.5% | 1.0% | 1.9% |
| Ngamiland-West | - | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.3% | 0.6% | 1.2% | 2.1% |
| Ngwaketse-West | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.4% | 0.8% |
| North-East | - | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.3% | 0.7% | 1.3% | 2.3% |
| Orapa | - | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.3% | 0.6% | 1.2% | 2.1% |
| Selebi-Phikwe | - | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.3% | 0.6% | 1.2% | 2.2% |
| Serowe-Palapye | - | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.3% | 0.6% | 1.2% | 2.1% |
| South-East | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.3% |
| Southern | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.2% | 0.5% | 1.0% |
| Sowa-Pan | - | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.3% | 0.6% | 1.1% | 2.0% |
| Tutme | - | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.2% | 0.5% | 0.9% | 1.8% |
| *Sum* | *-* | *0.0%* | *0.0%* | *0.0%* | *0.1%* | *0.1%* | *0.3%* | *0.6%* | *1.1%* | *2.0%* |
| **NATIONAL** | **-** | **0.0%** | **0.0%** | **0.0%** | **0.0%** | **0.1%** | **0.2%** | **0.5%** | **1.0%** | **1.8%** |

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| Barolong | 3.1% | 4.9% | 7.4% | 10.4% | 13.5% | 16.4% | 18.7% | 20.4% | 21.7% | 22.5% |
| Bobonong | 2.8% | 4.7% | 7.4% | 10.7% | 14.5% | 18.1% | 21.2% | 23.7% | 25.5% | 26.6% |
| C.Kgalagadi.G.R | 2.4% | 3.9% | 5.9% | 8.4% | 10.9% | 13.4% | 14.9% | 15.9% | 16.5% | 16.7% |
| Central-Boteti | 3.7% | 5.9% | 8.8% | 12.1% | 15.4% | 18.4% | 20.7% | 22.5% | 23.6% | 24.2% |
| Chobe | 3.2% | 5.6% | 9.3% | 14.0% | 19.3% | 24.2% | 28.2% | 31.1% | 32.8% | 33.7% |
| Francistown | 9.6% | 13.4% | 17.5% | 21.3% | 24.5% | 27.1% | 29.1% | 30.6% | 31.6% | 32.1% |
| Gaborone | 4.2% | 6.6% | 9.7% | 13.2% | 16.7% | 19.8% | 22.3% | 24.2% | 25.6% | 26.4% |
| Ghanzi | 2.7% | 4.2% | 6.2% | 8.6% | 10.9% | 13.0% | 14.6% | 15.8% | 16.5% | 16.8% |
| Jwaneng | 1.6% | 2.7% | 4.5% | 6.8% | 9.6% | 12.6% | 15.3% | 17.6% | 19.3% | 20.4% |
| Kgalagadi-North | 0.2% | 0.4% | 0.8% | 1.5% | 2.7% | 4.4% | 6.6% | 9.1% | 11.8% | 14.3% |
| Kgalagadi-South | 0.2% | 0.4% | 0.9% | 1.7% | 2.9% | 4.6% | 6.8% | 9.4% | 12.1% | 14.6% |
| Kgatleng | 2.3% | 3.8% | 5.9% | 8.5% | 11.4% | 14.1% | 16.4% | 18.2% | 19.5% | 20.4% |
| Kweneng-East | 2.3% | 3.8% | 5.9% | 8.6% | 11.7% | 14.6% | 17.2% | 19.2% | 20.7% | 21.7% |
| Kweneng-West | 0.9% | 1.6% | 2.7% | 4.3% | 6.4% | 8.9% | 11.4% | 13.7% | 15.7% | 17.1% |
| Lobatse | 4.7% | 7.4% | 10.8% | 14.6% | 18.1% | 21.2% | 23.4% | 24.9% | 25.9% | 26.2% |
| Mahalapye | 2.3% | 3.8% | 5.9% | 8.6% | 11.5% | 14.3% | 16.8% | 18.9% | 20.4% | 21.5% |
| Ngamiland-Delta | 2.1% | 3.8% | 6.4% | 9.9% | 14.2% | 18.7% | 22.8% | 26.0% | 28.3% | 29.6% |
| Ngamiland-East | 3.3% | 5.3% | 8.1% | 11.5% | 15.0% | 18.3% | 21.0% | 23.0% | 24.4% | 25.2% |
| Ngamiland-West | 3.7% | 5.9% | 8.8% | 12.3% | 15.8% | 19.0% | 21.6% | 23.4% | 24.6% | 25.2% |
| Ngwaketse-West | 1.6% | 2.8% | 4.5% | 6.9% | 9.8% | 12.8% | 15.6% | 17.9% | 19.5% | 20.6% |
| North-East | 3.9% | 6.0% | 8.9% | 12.2% | 15.4% | 18.4% | 20.8% | 22.6% | 23.9% | 24.6% |
| Orapa | 3.7% | 5.9% | 9.0% | 12.6% | 16.3% | 19.7% | 22.3% | 24.2% | 25.5% | 26.1% |
| Selebi-Phikwe | 4.0% | 6.7% | 10.5% | 15.4% | 20.6% | 25.6% | 29.8% | 33.0% | 35.3% | 36.8% |
| Serowe-Palapye | 3.7% | 5.9% | 8.8% | 12.3% | 16.0% | 19.3% | 22.1% | 24.2% | 25.7% | 26.7% |
| South-East | 0.6% | 1.1% | 2.1% | 3.7% | 5.9% | 8.7% | 12.2% | 15.9% | 19.2% | 21.9% |
| Southern | 1.8% | 3.0% | 4.8% | 7.2% | 9.9% | 12.6% | 14.9% | 16.8% | 18.2% | 19.0% |
| Sowa-Pan | 3.4% | 5.5% | 8.5% | 12.0% | 15.7% | 19.1% | 22.0% | 24.2% | 25.8% | 26.8% |
| Tutme | 3.0% | 4.9% | 7.5% | 10.7% | 14.1% | 17.4% | 20.1% | 22.2% | 23.8% | 24.9% |
| *Sum* | *3.3%* | *5.3%* | *7.9%* | *11.0%* | *14.2%* | *17.3%* | *19.9%* | *22.0%* | *23.5%* | *24.5%* |
| **NATIONAL** | **3.2%** | **5.2%** | **7.9%** | **11.2%** | **14.7%** | **17.9%** | **20.6%** | **22.6%** | **24.1%** | **25.0%** |

Note: The sum of the districts does not exactly equal the result from the national model due to slightly different models being applied to each district.

## Table A9.3 (cont) HIV prevalence, by district and year (2000-2019)

| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| Barolong | 22.8% | 22.7% | 22.4% | 22.0% | 21.6% | 21.1% | 20.8% | 20.6% | 20.6% | 20.7% |
| Bobonong | 27.2% | 27.3% | 27.0% | 26.6% | 26.1% | 25.7% | 25.4% | 25.2% | 25.0% | 24.9% |
| C.Kgalagadi.G.R | 16.6% | 16.2% | 15.7% | 15.1% | 14.5% | 14.1% | 13.8% | 13.6% | 13.4% | 13.2% |
| Central-Boteti | 24.4% | 24.1% | 23.5% | 22.8% | 22.2% | 21.6% | 21.2% | 20.9% | 20.6% | 20.4% |
| Chobe | 33.9% | 33.5% | 32.7% | 31.7% | 30.7% | 29.8% | 29.3% | 28.9% | 28.6% | 28.5% |
| Francistown | 32.2% | 31.9% | 31.4% | 30.8% | 30.4% | 30.0% | 29.6% | 29.3% | 29.0% | 28.7% |
| Gaborone | 26.8% | 26.8% | 26.6% | 26.3% | 26.1% | 25.9% | 25.7% | 25.5% | 25.3% | 25.1% |
| Ghanzi | 16.8% | 16.5% | 16.1% | 15.5% | 15.0% | 14.6% | 14.4% | 14.2% | 14.1% | 14.0% |
| Jwaneng | 21.0% | 21.1% | 21.0% | 20.8% | 20.6% | 20.5% | 20.3% | 20.2% | 20.0% | 19.9% |
| Kgalagadi-North | 16.4% | 17.8% | 18.8% | 19.4% | 19.8% | 20.0% | 20.2% | 20.2% | 20.2% | 20.2% |
| Kgalagadi-South | 16.6% | 18.0% | 19.0% | 19.6% | 20.0% | 20.4% | 20.6% | 20.8% | 20.8% | 20.9% |
| Kgatleng | 20.7% | 20.7% | 20.5% | 20.1% | 19.7% | 19.3% | 19.0% | 18.9% | 18.8% | 18.7% |
| Kweneng-East | 22.2% | 22.3% | 22.1% | 21.8% | 21.5% | 21.1% | 20.9% | 20.8% | 20.6% | 20.6% |
| Kweneng-West | 17.9% | 18.4% | 18.5% | 18.4% | 18.2% | 18.0% | 17.9% | 17.8% | 17.7% | 17.6% |
| Lobatse | 26.1% | 25.6% | 24.9% | 24.0% | 23.3% | 22.6% | 22.2% | 21.8% | 21.5% | 21.2% |
| Mahalapye | 22.1% | 22.3% | 22.3% | 22.0% | 21.8% | 21.7% | 21.6% | 21.5% | 21.4% | 21.3% |
| Ngamiland-Delta | 30.1% | 30.0% | 29.4% | 28.6% | 27.7% | 26.9% | 26.2% | 25.6% | 25.2% | 24.8% |
| Ngamiland-East | 25.4% | 25.3% | 24.8% | 24.1% | 23.5% | 23.1% | 22.7% | 22.3% | 22.0% | 21.7% |
| Ngamiland-West | 25.2% | 24.8% | 24.0% | 23.1% | 22.2% | 21.4% | 20.7% | 20.2% | 19.7% | 19.3% |
| Ngwaketse-West | 21.1% | 21.2% | 20.9% | 20.5% | 20.1% | 19.8% | 19.6% | 19.4% | 19.1% | 19.0% |
| North-East | 24.9% | 24.8% | 24.5% | 24.0% | 23.4% | 23.0% | 22.7% | 22.5% | 22.3% | 22.2% |
| Orapa | 26.2% | 25.8% | 25.2% | 24.4% | 23.8% | 23.2% | 22.8% | 22.5% | 22.3% | 22.1% |
| Selebi-Phikwe | 37.5% | 37.6% | 37.2% | 36.7% | 36.1% | 35.6% | 35.3% | 35.0% | 34.8% | 34.7% |
| Serowe-Palapye | 27.1% | 27.1% | 26.8% | 26.3% | 25.9% | 25.6% | 25.3% | 25.1% | 24.9% | 24.7% |
| South-East | 23.9% | 25.1% | 25.7% | 25.9% | 25.9% | 25.8% | 25.6% | 25.4% | 25.2% | 25.0% |
| Southern | 19.4% | 19.4% | 19.2% | 18.8% | 18.4% | 18.1% | 17.8% | 17.6% | 17.4% | 17.3% |
| Sowa-Pan | 27.4% | 27.4% | 27.2% | 26.8% | 26.5% | 26.3% | 26.1% | 26.0% | 25.9% | 25.8% |
| Tutme | 25.4% | 25.4% | 25.2% | 24.9% | 24.6% | 24.3% | 24.1% | 23.9% | 23.8% | 23.6% |
| *Sum* | *24.9%* | *25.0%* | *24.7%* | *24.4%* | *24.0%* | *23.6%* | *23.4%* | *23.1%* | *22.9%* | *22.8%* |
| **NATIONAL** | **25.4%** | **25.3%** | **25.0%** | **24.5%** | **24.1%** | **23.7%** | **23.4%** | **23.2%** | **23.0%** | **22.8%** |

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| Barolong | 20.8% | 21.1% | 21.3% | 21.5% | 21.7% | 21.9% | 22.1% | 22.2% | 22.4% | 22.6% |
| Bobonong | 24.8% | 24.8% | 24.9% | 24.9% | 25.0% | 25.1% | 25.2% | 25.3% | 25.4% | 25.5% |
| C.Kgalagadi.G.R | 13.1% | 13.1% | 13.1% | 13.1% | 13.1% | 13.1% | 13.2% | 13.3% | 13.3% | 13.5% |
| Central-Boteti | 20.2% | 20.2% | 20.1% | 20.1% | 20.0% | 20.0% | 20.1% | 20.1% | 20.1% | 20.2% |
| Chobe | 28.5% | 28.6% | 28.8% | 29.1% | 29.5% | 29.9% | 30.3% | 30.7% | 31.1% | 31.5% |
| Francistown | 28.4% | 28.3% | 28.1% | 28.0% | 27.9% | 27.8% | 27.8% | 27.8% | 27.8% | 27.8% |
| Gaborone | 24.9% | 24.9% | 24.8% | 24.8% | 24.8% | 24.8% | 24.9% | 25.0% | 25.1% | 25.2% |
| Ghanzi | 13.9% | 14.0% | 14.0% | 14.1% | 14.2% | 14.3% | 14.4% | 14.6% | 14.7% | 14.8% |
| Jwaneng | 19.8% | 19.7% | 19.7% | 19.8% | 19.8% | 19.9% | 20.0% | 20.2% | 20.3% | 20.5% |
| Kgalagadi-North | 20.1% | 20.0% | 20.0% | 20.0% | 20.0% | 20.1% | 20.1% | 20.2% | 20.3% | 20.5% |
| Kgalagadi-South | 20.8% | 20.9% | 20.9% | 20.9% | 20.9% | 21.0% | 21.1% | 21.2% | 21.3% | 21.4% |
| Kgatleng | 18.7% | 18.7% | 18.7% | 18.8% | 18.8% | 18.9% | 19.0% | 19.0% | 19.1% | 19.2% |
| Kweneng-East | 20.5% | 20.5% | 20.5% | 20.6% | 20.6% | 20.7% | 20.8% | 20.9% | 21.0% | 21.1% |
| Kweneng-West | 17.4% | 17.4% | 17.3% | 17.3% | 17.3% | 17.4% | 17.4% | 17.5% | 17.5% | 17.6% |
| Lobatse | 21.0% | 20.8% | 20.8% | 20.8% | 20.8% | 20.9% | 21.0% | 21.1% | 21.2% | 21.3% |
| Mahalapye | 21.2% | 21.1% | 21.1% | 21.1% | 21.1% | 21.1% | 21.2% | 21.2% | 21.2% | 21.3% |
| Ngamiland-Delta | 24.6% | 24.5% | 24.5% | 24.6% | 24.8% | 25.0% | 25.3% | 25.5% | 25.7% | 25.9% |
| Ngamiland-East | 21.5% | 21.3% | 21.3% | 21.2% | 21.3% | 21.3% | 21.4% | 21.5% | 21.6% | 21.7% |
| Ngamiland-West | 18.9% | 18.7% | 18.5% | 18.4% | 18.2% | 18.1% | 18.1% | 18.0% | 18.0% | 17.9% |
| Ngwaketse-West | 18.8% | 18.7% | 18.7% | 18.7% | 18.7% | 18.8% | 18.9% | 18.9% | 19.1% | 19.2% |
| North-East | 22.2% | 22.1% | 22.2% | 22.2% | 22.2% | 22.3% | 22.3% | 22.3% | 22.4% | 22.4% |
| Orapa | 22.0% | 22.0% | 22.1% | 22.2% | 22.4% | 22.5% | 22.7% | 22.9% | 23.1% | 23.3% |
| Selebi-Phikwe | 34.6% | 34.7% | 34.8% | 34.9% | 35.1% | 35.3% | 35.5% | 35.7% | 35.9% | 36.2% |
| Serowe-Palapye | 24.6% | 24.5% | 24.4% | 24.4% | 24.4% | 24.4% | 24.5% | 24.5% | 24.6% | 24.6% |
| South-East | 24.7% | 24.5% | 24.4% | 24.3% | 24.3% | 24.4% | 24.5% | 24.6% | 24.6% | 24.7% |
| Southern | 17.1% | 17.1% | 17.1% | 17.1% | 17.2% | 17.2% | 17.3% | 17.4% | 17.5% | 17.6% |
| Sowa-Pan | 25.8% | 25.9% | 26.0% | 26.1% | 26.2% | 26.4% | 26.5% | 26.6% | 26.7% | 26.7% |
| Tutme | 23.5% | 23.4% | 23.4% | 23.4% | 23.4% | 23.5% | 23.5% | 23.5% | 23.6% | 23.6% |
| *Sum* | *22.6%* | *22.6%* | *22.6%* | *22.6%* | *22.6%* | *22.6%* | *22.7%* | *22.8%* | *22.9%* | *22.9%* |
| **NATIONAL** | **22.7%** | **22.6%** | **22.6%** | **22.6%** | **22.6%** | **22.7%** | **22.7%** | **22.8%** | **22.9%** | **23.0%** |

Note: The sum of the districts does not exactly equal the result from the national model due to slightly different models being applied to each district.

## Table A9.3 (cont) HIV prevalence, by district and year (2020-2021)

| | 2020 | 2021 |
|---|---|---|
| Barolong | 22.7% | 22.9% |
| Bobonong | 25.6% | 25.7% |
| C.Kgalagadi.G.R | 13.6% | 13.7% |
| Central-Boteti | 20.2% | 20.3% |
| Chobe | 31.9% | 32.3% |
| Francistown | 27.8% | 27.8% |
| Gaborone | 25.3% | 25.4% |
| Ghanzi | 15.0% | 15.1% |
| Jwaneng | 20.6% | 20.8% |
| Kgalagadi-North | 20.6% | 20.8% |
| Kgalagadi-South | 21.6% | 21.7% |
| Kgatleng | 19.4% | 19.5% |
| Kweneng-East | 21.2% | 21.3% |
| Kweneng-West | 17.7% | 17.9% |
| Lobatse | 21.4% | 21.6% |
| Mahalapye | 21.3% | 21.4% |
| Ngamiland-Delta | 26.1% | 26.3% |
| Ngamiland-East | 21.8% | 21.9% |
| Ngamiland-West | 17.8% | 17.8% |
| Ngwaketse-West | 19.3% | 19.5% |
| North-East | 22.5% | 22.6% |
| Orapa | 23.5% | 23.7% |
| Selebi-Phikwe | 36.4% | 36.6% |
| Serowe-Palapye | 24.7% | 24.8% |
| South-East | 24.8% | 24.9% |
| Southern | 17.7% | 17.9% |
| Sowa-Pan | 26.8% | 26.9% |
| Tutme | 23.7% | 23.8% |
| *Sum* | *23.0%* | *23.1%* |
| **NATIONAL** | **23.1%** | **23.3%** |

Note: The sum of the districts does not exactly equal the result from the national model due to slightly different models being applied to each district.

## A9.4 Numbers of HIV+ males, by single age and year (2006-2021)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 25 325 | 24 995 | 24 736 | 24 532 | 24 374 | 24 253 | 24 163 | 24 098 | 24 054 | 24 023 | 23 998 | 23 976 | 23 945 | 23 901 | 23 839 | 23 753 |
| **1** | 25 374 | 24 959 | 24 638 | 24 382 | 24 183 | 24 029 | 23 913 | 23 827 | 23 768 | 23 727 | 23 700 | 23 681 | 23 662 | 23 635 | 23 595 | 23 537 |
| **2** | 25 631 | 25 169 | 24 755 | 24 434 | 24 179 | 23 981 | 23 828 | 23 713 | 23 629 | 23 571 | 23 533 | 23 507 | 23 488 | 23 471 | 23 446 | 23 407 |
| **3** | 25 953 | 25 490 | 25 018 | 24 604 | 24 283 | 24 028 | 23 831 | 23 680 | 23 566 | 23 483 | 23 426 | 23 389 | 23 364 | 23 347 | 23 331 | 23 306 |
| **4** | 26 358 | 25 856 | 25 375 | 24 894 | 24 480 | 24 158 | 23 905 | 23 709 | 23 558 | 23 446 | 23 364 | 23 308 | 23 272 | 23 248 | 23 231 | 23 216 |
| **5** | 26 932 | 26 287 | 25 770 | 25 274 | 24 786 | 24 372 | 24 050 | 23 798 | 23 603 | 23 453 | 23 342 | 23 261 | 23 206 | 23 170 | 23 147 | 23 131 |
| **6** | 26 764 | 26 875 | 26 215 | 25 687 | 25 179 | 24 686 | 24 273 | 23 951 | 23 700 | 23 506 | 23 358 | 23 248 | 23 168 | 23 114 | 23 079 | 23 057 |
| **7** | 26 687 | 26 716 | 26 813 | 26 142 | 25 606 | 25 089 | 24 592 | 24 180 | 23 860 | 23 610 | 23 417 | 23 270 | 23 161 | 23 082 | 23 029 | 22 995 |
| **8** | 26 644 | 26 638 | 26 659 | 26 745 | 26 066 | 25 524 | 25 002 | 24 503 | 24 092 | 23 773 | 23 524 | 23 333 | 23 187 | 23 079 | 23 001 | 22 949 |
| **9** | 26 590 | 26 591 | 26 579 | 26 593 | 26 670 | 25 986 | 25 442 | 24 916 | 24 415 | 24 006 | 23 688 | 23 441 | 23 251 | 23 106 | 22 999 | 22 923 |
| **10** | 26 516 | 26 532 | 26 528 | 26 510 | 26 518 | 26 588 | 25 901 | 25 356 | 24 829 | 24 328 | 23 921 | 23 603 | 23 358 | 23 169 | 23 026 | 22 920 |
| **11** | 26 439 | 26 455 | 26 464 | 26 454 | 26 432 | 26 435 | 26 499 | 25 811 | 25 268 | 24 741 | 24 240 | 23 835 | 23 519 | 23 275 | 23 088 | 22 946 |
| **12** | 26 325 | 26 376 | 26 385 | 26 388 | 26 373 | 26 345 | 26 344 | 26 405 | 25 717 | 25 178 | 24 653 | 24 153 | 23 750 | 23 435 | 23 193 | 23 007 |
| **13** | 26 162 | 26 264 | 26 308 | 26 308 | 26 304 | 26 283 | 26 250 | 26 245 | 26 304 | 25 618 | 25 085 | 24 563 | 24 064 | 23 664 | 23 351 | 23 110 |
| **14** | 25 919 | 26 103 | 26 196 | 26 228 | 26 218 | 26 202 | 26 170 | 26 126 | 26 107 | 26 147 | 25 448 | 24 909 | 24 379 | 23 877 | 23 480 | 23 170 |
| **15** | 25 562 | 25 861 | 26 036 | 26 119 | 26 142 | 26 122 | 26 098 | 26 060 | 26 012 | 25 992 | 26 034 | 25 342 | 24 815 | 24 293 | 23 795 | 23 402 |
| **16** | 25 014 | 25 508 | 25 800 | 25 968 | 26 041 | 26 053 | 26 023 | 25 992 | 25 948 | 25 895 | 25 875 | 25 919 | 25 234 | 24 720 | 24 206 | 23 712 |
| **17** | 24 443 | 24 960 | 25 449 | 25 735 | 25 895 | 25 958 | 25 960 | 25 921 | 25 882 | 25 833 | 25 777 | 25 756 | 25 803 | 25 125 | 24 622 | 24 117 |
| **18** | 23 855 | 24 381 | 24 896 | 25 381 | 25 662 | 25 814 | 25 869 | 25 862 | 25 815 | 25 769 | 25 715 | 25 656 | 25 635 | 25 684 | 25 014 | 24 522 |
| **19** | 23 244 | 23 784 | 24 310 | 24 823 | 25 306 | 25 582 | 25 728 | 25 775 | 25 760 | 25 705 | 25 654 | 25 596 | 25 535 | 25 514 | 25 566 | 24 903 |
| **20** | 22 615 | 23 164 | 23 706 | 24 232 | 24 744 | 25 225 | 25 497 | 25 638 | 25 678 | 25 656 | 25 595 | 25 539 | 25 478 | 25 415 | 25 395 | 25 449 |
| **21** | 21 943 | 22 529 | 23 080 | 23 623 | 24 150 | 24 662 | 25 140 | 25 410 | 25 546 | 25 580 | 25 552 | 25 486 | 25 426 | 25 362 | 25 297 | 25 278 |
| **22** | 21 197 | 21 855 | 22 443 | 22 996 | 23 540 | 24 067 | 24 578 | 25 056 | 25 323 | 25 455 | 25 484 | 25 450 | 25 379 | 25 315 | 25 249 | 25 183 |
| **23** | 20 373 | 21 113 | 21 772 | 22 362 | 22 915 | 23 459 | 23 986 | 24 497 | 24 972 | 25 237 | 25 364 | 25 389 | 25 350 | 25 275 | 25 208 | 25 139 |
| **24** | 19 515 | 20 299 | 21 038 | 21 697 | 22 286 | 22 839 | 23 383 | 23 909 | 24 418 | 24 891 | 25 152 | 25 276 | 25 296 | 25 253 | 25 174 | 25 103 |
| **25** | 18 677 | 19 453 | 20 235 | 20 973 | 21 631 | 22 218 | 22 770 | 23 312 | 23 836 | 24 343 | 24 813 | 25 071 | 25 191 | 25 206 | 25 158 | 25 075 |
| **26** | 16 286 | 18 619 | 19 393 | 20 172 | 20 908 | 21 563 | 22 148 | 22 698 | 23 238 | 23 760 | 24 264 | 24 730 | 24 985 | 25 101 | 25 112 | 25 060 |
| **27** | 15 947 | 16 230 | 18 553 | 19 324 | 20 101 | 20 834 | 21 486 | 22 069 | 22 617 | 23 154 | 23 674 | 24 175 | 24 639 | 24 890 | 25 003 | 25 010 |
| **28** | 15 491 | 15 875 | 16 159 | 18 470 | 19 239 | 20 014 | 20 744 | 21 394 | 21 975 | 22 520 | 23 056 | 23 573 | 24 071 | 24 531 | 24 780 | 24 889 |
| **29** | 15 062 | 15 392 | 15 778 | 16 065 | 18 364 | 19 132 | 19 904 | 20 632 | 21 280 | 21 859 | 22 402 | 22 933 | 23 445 | 23 935 | 24 383 | 24 614 |
| **30** | 14 607 | 14 931 | 15 266 | 15 654 | 15 944 | 18 229 | 18 996 | 19 767 | 20 493 | 21 139 | 21 716 | 22 256 | 22 786 | 23 295 | 23 782 | 24 228 |
| **31** | 14 061 | 14 441 | 14 770 | 15 108 | 15 500 | 15 793 | 18 062 | 18 828 | 19 597 | 20 321 | 20 966 | 21 540 | 22 078 | 22 605 | 23 111 | 23 596 |
| **32** | 13 415 | 13 860 | 14 244 | 14 576 | 14 917 | 15 312 | 15 611 | 17 860 | 18 625 | 19 392 | 20 114 | 20 755 | 21 327 | 21 863 | 22 386 | 22 889 |
| **33** | 12 658 | 13 185 | 13 631 | 14 014 | 14 348 | 14 692 | 15 091 | 15 395 | 17 622 | 18 385 | 19 149 | 19 867 | 20 505 | 21 074 | 21 606 | 22 126 |
| **34** | 11 845 | 12 407 | 12 930 | 13 371 | 13 753 | 14 087 | 14 435 | 14 837 | 15 147 | 17 347 | 18 107 | 18 867 | 19 581 | 20 215 | 20 779 | 21 307 |
| **35** | 11 065 | 11 583 | 12 137 | 12 650 | 13 084 | 13 462 | 13 798 | 14 149 | 14 554 | 14 868 | 17 037 | 17 793 | 18 547 | 19 255 | 19 884 | 20 443 |
| **36** | 10 352 | 10 799 | 11 307 | 11 846 | 12 346 | 12 772 | 13 147 | 13 484 | 13 837 | 14 244 | 14 562 | 16 696 | 17 445 | 18 192 | 18 893 | 19 515 |
| **37** | 9 675 | 10 086 | 10 524 | 11 016 | 11 538 | 12 025 | 12 442 | 12 814 | 13 151 | 13 505 | 13 913 | 14 233 | 16 327 | 17 069 | 17 807 | 18 499 |
| **38** | 9 040 | 9 416 | 9 817 | 10 238 | 10 712 | 11 217 | 11 690 | 12 100 | 12 467 | 12 803 | 13 158 | 13 565 | 13 886 | 15 937 | 16 668 | 17 396 |
| **39** | 8 451 | 8 790 | 9 156 | 9 541 | 9 945 | 10 401 | 10 889 | 11 348 | 11 750 | 12 113 | 12 448 | 12 801 | 13 205 | 13 525 | 15 531 | 16 250 |
| **40** | 7 884 | 8 213 | 8 543 | 8 894 | 9 261 | 9 647 | 10 086 | 10 557 | 11 005 | 11 398 | 11 756 | 12 088 | 12 439 | 12 839 | 13 157 | 15 114 |
| **41** | 7 366 | 7 661 | 7 979 | 8 295 | 8 629 | 8 979 | 9 349 | 9 772 | 10 229 | 10 664 | 11 049 | 11 402 | 11 730 | 12 076 | 12 471 | 12 785 |
| **42** | 6 947 | 7 156 | 7 442 | 7 747 | 8 046 | 8 365 | 8 700 | 9 055 | 9 463 | 9 906 | 10 330 | 10 706 | 11 053 | 11 376 | 11 717 | 12 105 |
| **43** | 6 651 | 6 750 | 6 953 | 7 225 | 7 515 | 7 800 | 8 104 | 8 425 | 8 767 | 9 162 | 9 592 | 10 005 | 10 373 | 10 713 | 11 030 | 11 366 |
| **44** | 6 442 | 6 463 | 6 560 | 6 752 | 7 011 | 7 286 | 7 558 | 7 849 | 8 158 | 8 489 | 8 871 | 9 289 | 9 691 | 10 051 | 10 384 | 10 695 |
| **45** | 6 282 | 6 262 | 6 283 | 6 372 | 6 553 | 6 799 | 7 062 | 7 322 | 7 602 | 7 900 | 8 221 | 8 592 | 8 999 | 9 391 | 9 743 | 10 068 |
| **46** | 6 124 | 6 109 | 6 089 | 6 105 | 6 187 | 6 358 | 6 592 | 6 844 | 7 094 | 7 365 | 7 654 | 7 966 | 8 327 | 8 723 | 9 105 | 9 448 |
| **47** | 5 940 | 5 957 | 5 942 | 5 919 | 5 930 | 6 005 | 6 167 | 6 392 | 6 634 | 6 876 | 7 139 | 7 420 | 7 723 | 8 075 | 8 461 | 8 833 |
| **48** | 5 704 | 5 780 | 5 796 | 5 778 | 5 752 | 5 758 | 5 828 | 5 983 | 6 199 | 6 434 | 6 669 | 6 924 | 7 198 | 7 493 | 7 836 | 8 211 |
| **49** | 5 438 | 5 552 | 5 625 | 5 637 | 5 616 | 5 587 | 5 591 | 5 656 | 5 805 | 6 015 | 6 243 | 6 471 | 6 720 | 6 987 | 7 274 | 7 607 |
| **50** | 5 191 | 5 295 | 5 405 | 5 473 | 5 481 | 5 458 | 5 427 | 5 429 | 5 491 | 5 635 | 5 839 | 6 061 | 6 284 | 6 526 | 6 785 | 7 062 |
| **51** | 4 979 | 5 056 | 5 157 | 5 261 | 5 323 | 5 328 | 5 304 | 5 272 | 5 273 | 5 333 | 5 474 | 5 672 | 5 888 | 6 105 | 6 339 | 6 588 |
| **52** | 4 770 | 4 851 | 4 925 | 5 020 | 5 118 | 5 176 | 5 180 | 5 154 | 5 123 | 5 124 | 5 183 | 5 320 | 5 513 | 5 723 | 5 931 | 6 155 |
| **53** | 4 555 | 4 648 | 4 726 | 4 795 | 4 885 | 4 979 | 5 034 | 5 036 | 5 011 | 4 981 | 4 982 | 5 040 | 5 173 | 5 360 | 5 561 | 5 759 |
| **54** | 4 333 | 4 440 | 4 529 | 4 603 | 4 668 | 4 753 | 4 842 | 4 895 | 4 897 | 4 873 | 4 844 | 4 846 | 4 902 | 5 030 | 5 210 | 5 400 |
| **55** | 4 099 | 4 224 | 4 326 | 4 411 | 4 480 | 4 542 | 4 624 | 4 710 | 4 761 | 4 764 | 4 741 | 4 713 | 4 715 | 4 768 | 4 890 | 5 059 |
| **56** | 3 864 | 3 996 | 4 117 | 4 214 | 4 294 | 4 359 | 4 418 | 4 498 | 4 582 | 4 632 | 4 635 | 4 614 | 4 587 | 4 587 | 4 636 | 4 749 |
| **57** | 3 649 | 3 768 | 3 895 | 4 010 | 4 102 | 4 178 | 4 241 | 4 298 | 4 376 | 4 458 | 4 508 | 4 512 | 4 491 | 4 464 | 4 461 | 4 504 |
| **58** | 3 470 | 3 559 | 3 672 | 3 793 | 3 902 | 3 990 | 4 063 | 4 125 | 4 181 | 4 257 | 4 339 | 4 388 | 4 392 | 4 371 | 4 342 | 4 335 |
| **59** | 3 320 | 3 383 | 3 468 | 3 575 | 3 690 | 3 795 | 3 879 | 3 951 | 4 011 | 4 067 | 4 142 | 4 222 | 4 271 | 4 275 | 4 252 | 4 219 |
| **60** | 3 182 | 3 237 | 3 296 | 3 375 | 3 477 | 3 588 | 3 688 | 3 770 | 3 840 | 3 900 | 3 955 | 4 030 | 4 109 | 4 156 | 4 158 | 4 132 |
| **61** | 3 045 | 3 102 | 3 152 | 3 208 | 3 282 | 3 379 | 3 485 | 3 583 | 3 663 | 3 732 | 3 791 | 3 847 | 3 920 | 3 997 | 4 042 | 4 040 |
| **62** | 2 910 | 2 966 | 3 020 | 3 067 | 3 118 | 3 189 | 3 281 | 3 384 | 3 479 | 3 558 | 3 626 | 3 685 | 3 740 | 3 813 | 3 887 | 3 928 |
| **63** | 2 773 | 2 833 | 2 887 | 2 936 | 2 979 | 3 027 | 3 095 | 3 184 | 3 284 | 3 377 | 3 455 | 3 522 | 3 581 | 3 636 | 3 706 | 3 776 |
| **64** | 2 633 | 2 698 | 2 755 | 2 805 | 2 851 | 2 891 | 2 936 | 3 001 | 3 088 | 3 185 | 3 276 | 3 353 | 3 420 | 3 479 | 3 532 | 3 598 |
| **65** | 2 488 | 2 559 | 2 622 | 2 675 | 2 721 | 2 764 | 2 801 | 2 845 | 2 907 | 2 992 | 3 087 | 3 177 | 3 253 | 3 320 | 3 377 | 3 427 |
| **66** | 2 347 | 2 416 | 2 484 | 2 543 | 2 593 | 2 636 | 2 676 | 2 712 | 2 754 | 2 815 | 2 898 | 2 991 | 3 080 | 3 155 | 3 220 | 3 275 |
| **67** | 2 218 | 2 277 | 2 343 | 2 408 | 2 463 | 2 510 | 2 550 | 2 589 | 2 623 | 2 664 | 2 724 | 2 805 | 2 897 | 2 984 | 3 057 | 3 120 |
| **68** | 2 105 | 2 149 | 2 206 | 2 269 | 2 330 | 2 382 | 2 426 | 2 464 | 2 501 | 2 535 | 2 574 | 2 633 | 2 713 | 2 802 | 2 887 | 2 959 |
| **69** | 2 008 | 2 036 | 2 078 | 2 132 | 2 192 | 2 249 | 2 299 | 2 340 | 2 377 | 2 413 | 2 445 | 2 484 | 2 542 | 2 620 | 2 707 | 2 789 |
| **70** | 1 925 | 1 939 | 1 966 | 2 005 | 2 056 | 2 113 | 2 167 | 2 214 | 2 254 | 2 289 | 2 324 | 2 355 | 2 394 | 2 450 | 2 526 | 2 611 |
| **71** | 1 844 | 1 854 | 1 867 | 1 893 | 1 930 | 1 979 | 2 032 | 2 084 | 2 129 | 2 167 | 2 201 | 2 234 | 2 265 | 2 303 | 2 357 | 2 431 |
| **72** | 1 752 | 1 771 | 1 781 | 1 794 | 1 818 | 1 854 | 1 899 | 1 950 | 2 000 | 2 042 | 2 079 | 2 111 | 2 144 | 2 174 | 2 211 | 2 264 |
| **73** | 1 643 | 1 677 | 1 696 | 1 706 | 1 718 | 1 741 | 1 775 | 1 818 | 1 867 | 1 914 | 1 955 | 1 990 | 2 021 | 2 053 | 2 082 | 2 118 |
| **74** | 1 516 | 1 566 | 1 600 | 1 618 | 1 628 | 1 640 | 1 662 | 1 694 | 1 735 | 1 781 | 1 826 | 1 865 | 1 899 | 1 929 | 1 960 | 1 989 |
| **75+** | 10 636 | 11 036 | 11 453 | 11 873 | 12 278 | 12 663 | 13 029 | 13 387 | 13 746 | 14 115 | 14 498 | 14 893 | 15 295 | 15 696 | 16 095 | 16 490 |

## A9.5 Numbers of HIV+ females, by single age and year (2006-2021)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 25 024 | 24 697 | 24 438 | 24 236 | 24 078 | 23 956 | 23 866 | 23 801 | 23 756 | 23 723 | 23 698 | 23 674 | 23 643 | 23 598 | 23 535 | 23 450 |
| **1** | 25 105 | 24 691 | 24 371 | 24 115 | 23 916 | 23 761 | 23 643 | 23 556 | 23 495 | 23 453 | 23 424 | 23 403 | 23 383 | 23 354 | 23 313 | 23 254 |
| **2** | 25 368 | 24 908 | 24 495 | 24 175 | 23 919 | 23 720 | 23 567 | 23 450 | 23 365 | 23 305 | 23 265 | 23 237 | 23 216 | 23 198 | 23 170 | 23 130 |
| **3** | 25 694 | 25 232 | 24 762 | 24 349 | 24 027 | 23 772 | 23 575 | 23 422 | 23 306 | 23 222 | 23 164 | 23 124 | 23 097 | 23 078 | 23 060 | 23 034 |
| **4** | 26 101 | 25 601 | 25 121 | 24 641 | 24 228 | 23 906 | 23 652 | 23 455 | 23 303 | 23 189 | 23 106 | 23 048 | 23 009 | 22 983 | 22 965 | 22 947 |
| **5** | 26 676 | 26 032 | 25 517 | 25 022 | 24 535 | 24 122 | 23 800 | 23 547 | 23 351 | 23 200 | 23 087 | 23 005 | 22 948 | 22 910 | 22 885 | 22 867 |
| **6** | 26 528 | 26 618 | 25 961 | 25 434 | 24 928 | 24 436 | 24 023 | 23 702 | 23 450 | 23 255 | 23 106 | 22 994 | 22 912 | 22 856 | 22 820 | 22 795 |
| **7** | 26 460 | 26 478 | 26 555 | 25 887 | 25 351 | 24 837 | 24 341 | 23 930 | 23 610 | 23 359 | 23 166 | 23 018 | 22 907 | 22 826 | 22 772 | 22 736 |
| **8** | 26 418 | 26 407 | 26 418 | 26 483 | 25 808 | 25 267 | 24 747 | 24 249 | 23 840 | 23 520 | 23 272 | 23 080 | 22 933 | 22 823 | 22 744 | 22 690 |
| **9** | 26 357 | 26 358 | 26 342 | 26 346 | 26 403 | 25 723 | 25 180 | 24 657 | 24 158 | 23 750 | 23 432 | 23 185 | 22 995 | 22 849 | 22 741 | 22 663 |
| **10** | 26 272 | 26 290 | 26 286 | 26 265 | 26 263 | 26 314 | 25 630 | 25 088 | 24 563 | 24 064 | 23 659 | 23 342 | 23 097 | 22 908 | 22 764 | 22 656 |
| **11** | 26 183 | 26 203 | 26 215 | 26 206 | 26 180 | 26 173 | 26 219 | 25 535 | 24 995 | 24 470 | 23 972 | 23 569 | 23 254 | 23 010 | 22 822 | 22 680 |
| **12** | 26 062 | 26 116 | 26 129 | 26 135 | 26 121 | 26 090 | 26 080 | 26 122 | 25 438 | 24 903 | 24 380 | 23 883 | 23 482 | 23 169 | 22 927 | 22 741 |
| **13** | 25 894 | 25 998 | 26 045 | 26 050 | 26 049 | 26 029 | 25 994 | 25 980 | 26 020 | 25 338 | 24 809 | 24 290 | 23 795 | 23 396 | 23 085 | 22 844 |
| **14** | 25 649 | 25 832 | 25 926 | 25 963 | 25 957 | 25 945 | 25 915 | 25 869 | 25 842 | 25 863 | 25 169 | 24 634 | 24 107 | 23 608 | 23 214 | 22 905 |
| **15** | 25 297 | 25 585 | 25 761 | 25 846 | 25 873 | 25 858 | 25 839 | 25 803 | 25 753 | 25 725 | 25 749 | 25 063 | 24 539 | 24 021 | 23 526 | 23 135 |
| **16** | 24 764 | 25 236 | 25 519 | 25 686 | 25 762 | 25 779 | 25 756 | 25 729 | 25 688 | 25 634 | 25 606 | 25 633 | 24 953 | 24 442 | 23 932 | 23 442 |
| **17** | 24 200 | 24 701 | 25 169 | 25 446 | 25 607 | 25 674 | 25 681 | 25 649 | 25 615 | 25 569 | 25 512 | 25 484 | 25 513 | 24 842 | 24 343 | 23 841 |
| **18** | 23 614 | 24 130 | 24 630 | 25 095 | 25 367 | 25 520 | 25 579 | 25 578 | 25 538 | 25 498 | 25 448 | 25 388 | 25 360 | 25 392 | 24 728 | 24 240 |
| **19** | 23 003 | 23 536 | 24 052 | 24 550 | 25 013 | 25 281 | 25 428 | 25 480 | 25 471 | 25 424 | 25 378 | 25 324 | 25 263 | 25 235 | 25 270 | 24 613 |
| **20** | 22 366 | 22 914 | 23 448 | 23 964 | 24 462 | 24 922 | 25 187 | 25 330 | 25 375 | 25 359 | 25 306 | 25 256 | 25 199 | 25 136 | 25 109 | 25 146 |
| **21** | 21 679 | 22 262 | 22 813 | 23 348 | 23 866 | 24 364 | 24 823 | 25 085 | 25 223 | 25 263 | 25 242 | 25 184 | 25 130 | 25 070 | 25 006 | 24 979 |
| **22** | 20 915 | 21 558 | 22 145 | 22 698 | 23 236 | 23 755 | 24 253 | 24 711 | 24 971 | 25 107 | 25 142 | 25 115 | 25 053 | 24 996 | 24 934 | 24 869 |
| **23** | 20 061 | 20 773 | 21 420 | 22 010 | 22 566 | 23 106 | 23 626 | 24 125 | 24 582 | 24 841 | 24 973 | 25 005 | 24 975 | 24 909 | 24 849 | 24 786 |
| **24** | 19 135 | 19 892 | 20 608 | 21 259 | 21 851 | 22 409 | 22 951 | 23 473 | 23 972 | 24 429 | 24 687 | 24 817 | 24 845 | 24 812 | 24 743 | 24 681 |
| **25** | 18 177 | 18 937 | 19 697 | 20 415 | 21 068 | 21 662 | 22 223 | 22 766 | 23 289 | 23 789 | 24 245 | 24 501 | 24 629 | 24 655 | 24 619 | 24 548 |
| **26** | 16 754 | 17 942 | 18 703 | 19 463 | 20 181 | 20 834 | 21 431 | 21 993 | 22 538 | 23 062 | 23 562 | 24 017 | 24 273 | 24 400 | 24 424 | 24 386 |
| **27** | 16 045 | 16 487 | 17 666 | 18 424 | 19 180 | 19 896 | 20 550 | 21 148 | 21 713 | 22 259 | 22 785 | 23 284 | 23 738 | 23 994 | 24 120 | 24 143 |
| **28** | 15 220 | 15 736 | 16 180 | 17 344 | 18 094 | 18 844 | 19 559 | 20 213 | 20 812 | 21 378 | 21 927 | 22 452 | 22 952 | 23 404 | 23 659 | 23 786 |
| **29** | 14 430 | 14 878 | 15 391 | 15 830 | 16 972 | 17 713 | 18 458 | 19 169 | 19 822 | 20 423 | 20 990 | 21 537 | 22 061 | 22 554 | 22 995 | 23 236 |
| **30** | 13 670 | 14 062 | 14 507 | 15 010 | 15 439 | 16 557 | 17 287 | 18 025 | 18 732 | 19 384 | 19 985 | 20 552 | 21 100 | 21 622 | 22 114 | 22 554 |
| **31** | 12 922 | 13 288 | 13 676 | 14 108 | 14 595 | 15 014 | 16 105 | 16 825 | 17 554 | 18 256 | 18 905 | 19 505 | 20 071 | 20 617 | 21 138 | 21 627 |
| **32** | 12 199 | 12 538 | 12 898 | 13 271 | 13 685 | 14 155 | 14 563 | 15 627 | 16 334 | 17 054 | 17 750 | 18 395 | 18 992 | 19 555 | 20 099 | 20 616 |
| **33** | 11 497 | 11 823 | 12 154 | 12 496 | 12 850 | 13 246 | 13 698 | 14 095 | 15 130 | 15 825 | 16 535 | 17 222 | 17 862 | 18 454 | 19 014 | 19 553 |
| **34** | 10 845 | 11 137 | 11 453 | 11 765 | 12 087 | 12 420 | 12 797 | 13 233 | 13 618 | 14 625 | 15 307 | 16 005 | 16 684 | 17 316 | 17 903 | 18 457 |
| **35** | 10 280 | 10 505 | 10 786 | 11 083 | 11 374 | 11 674 | 11 988 | 12 346 | 12 766 | 13 142 | 14 120 | 14 788 | 15 474 | 16 142 | 16 766 | 17 345 |
| **36** | 9 813 | 9 961 | 10 177 | 10 440 | 10 715 | 10 984 | 11 263 | 11 558 | 11 900 | 12 305 | 12 672 | 13 622 | 14 276 | 14 949 | 15 606 | 16 220 |
| **37** | 9 414 | 9 513 | 9 655 | 9 855 | 10 098 | 10 351 | 10 599 | 10 859 | 11 138 | 11 465 | 11 857 | 12 214 | 13 137 | 13 777 | 14 436 | 15 081 |
| **38** | 9 071 | 9 131 | 9 226 | 9 355 | 9 538 | 9 760 | 9 993 | 10 223 | 10 466 | 10 731 | 11 045 | 11 425 | 11 773 | 12 670 | 13 295 | 13 941 |
| **39** | 8 765 | 8 802 | 8 860 | 8 945 | 9 061 | 9 227 | 9 431 | 9 646 | 9 860 | 10 089 | 10 341 | 10 644 | 11 012 | 11 353 | 12 224 | 12 834 |
| **40** | 8 476 | 8 509 | 8 545 | 8 596 | 8 670 | 8 773 | 8 924 | 9 112 | 9 313 | 9 513 | 9 730 | 9 971 | 10 264 | 10 621 | 10 954 | 11 801 |
| **41** | 8 199 | 8 232 | 8 265 | 8 295 | 8 338 | 8 402 | 8 493 | 8 632 | 8 807 | 8 995 | 9 184 | 9 391 | 9 623 | 9 906 | 10 254 | 10 580 |
| **42** | 7 944 | 7 968 | 8 001 | 8 028 | 8 052 | 8 087 | 8 142 | 8 225 | 8 353 | 8 517 | 8 695 | 8 875 | 9 073 | 9 297 | 9 572 | 9 911 |
| **43** | 7 713 | 7 725 | 7 749 | 7 777 | 7 798 | 7 815 | 7 844 | 7 893 | 7 968 | 8 088 | 8 244 | 8 413 | 8 585 | 8 776 | 8 993 | 9 261 |
| **44** | 7 505 | 7 507 | 7 518 | 7 538 | 7 559 | 7 575 | 7 587 | 7 610 | 7 655 | 7 725 | 7 839 | 7 988 | 8 149 | 8 315 | 8 498 | 8 708 |
| **45** | 7 314 | 7 311 | 7 312 | 7 319 | 7 332 | 7 348 | 7 359 | 7 368 | 7 389 | 7 429 | 7 496 | 7 604 | 7 747 | 7 901 | 8 058 | 8 232 |
| **46** | 7 129 | 7 132 | 7 128 | 7 125 | 7 126 | 7 134 | 7 146 | 7 153 | 7 160 | 7 179 | 7 217 | 7 280 | 7 384 | 7 519 | 7 663 | 7 808 |
| **47** | 6 941 | 6 960 | 6 961 | 6 952 | 6 943 | 6 940 | 6 944 | 6 952 | 6 958 | 6 963 | 6 981 | 7 017 | 7 076 | 7 172 | 7 296 | 7 425 |
| **48** | 6 744 | 6 785 | 6 800 | 6 796 | 6 782 | 6 768 | 6 761 | 6 762 | 6 768 | 6 773 | 6 778 | 6 794 | 6 827 | 6 879 | 6 964 | 7 071 |
| **49** | 6 533 | 6 600 | 6 636 | 6 645 | 6 636 | 6 617 | 6 601 | 6 590 | 6 590 | 6 595 | 6 599 | 6 602 | 6 615 | 6 642 | 6 685 | 6 754 |
| **50** | 6 311 | 6 402 | 6 462 | 6 492 | 6 495 | 6 481 | 6 460 | 6 441 | 6 429 | 6 427 | 6 431 | 6 434 | 6 435 | 6 443 | 6 461 | 6 490 |
| **51** | 6 073 | 6 191 | 6 275 | 6 328 | 6 352 | 6 350 | 6 333 | 6 310 | 6 289 | 6 276 | 6 274 | 6 277 | 6 277 | 6 273 | 6 273 | 6 279 |
| **52** | 5 820 | 5 965 | 6 076 | 6 152 | 6 198 | 6 216 | 6 211 | 6 192 | 6 167 | 6 146 | 6 133 | 6 129 | 6 129 | 6 125 | 6 115 | 6 104 |
| **53** | 5 556 | 5 723 | 5 861 | 5 963 | 6 032 | 6 072 | 6 086 | 6 078 | 6 058 | 6 033 | 6 011 | 5 997 | 5 991 | 5 988 | 5 978 | 5 959 |
| **54** | 5 284 | 5 470 | 5 629 | 5 759 | 5 853 | 5 916 | 5 951 | 5 961 | 5 952 | 5 931 | 5 906 | 5 884 | 5 868 | 5 859 | 5 851 | 5 833 |
| **55** | 5 007 | 5 207 | 5 385 | 5 537 | 5 658 | 5 746 | 5 803 | 5 834 | 5 843 | 5 833 | 5 811 | 5 786 | 5 763 | 5 745 | 5 731 | 5 717 |
| **56** | 4 735 | 4 937 | 5 131 | 5 301 | 5 445 | 5 559 | 5 641 | 5 693 | 5 722 | 5 729 | 5 719 | 5 698 | 5 671 | 5 646 | 5 624 | 5 605 |
| **57** | 4 479 | 4 672 | 4 868 | 5 054 | 5 218 | 5 354 | 5 462 | 5 539 | 5 588 | 5 615 | 5 621 | 5 611 | 5 589 | 5 561 | 5 533 | 5 505 |
| **58** | 4 242 | 4 421 | 4 608 | 4 798 | 4 977 | 5 134 | 5 264 | 5 367 | 5 440 | 5 487 | 5 512 | 5 518 | 5 506 | 5 483 | 5 452 | 5 420 |
| **59** | 4 029 | 4 187 | 4 361 | 4 543 | 4 727 | 4 900 | 5 050 | 5 175 | 5 274 | 5 344 | 5 388 | 5 412 | 5 417 | 5 405 | 5 379 | 5 345 |
| **60** | 3 840 | 3 975 | 4 130 | 4 299 | 4 476 | 4 655 | 4 822 | 4 967 | 5 087 | 5 183 | 5 250 | 5 293 | 5 316 | 5 319 | 5 305 | 5 276 |
| **61** | 3 670 | 3 788 | 3 920 | 4 071 | 4 236 | 4 409 | 4 582 | 4 744 | 4 884 | 5 001 | 5 093 | 5 158 | 5 199 | 5 221 | 5 223 | 5 206 |
| **62** | 3 513 | 3 619 | 3 734 | 3 864 | 4 011 | 4 172 | 4 340 | 4 508 | 4 666 | 4 802 | 4 916 | 5 005 | 5 068 | 5 108 | 5 128 | 5 127 |
| **63** | 3 358 | 3 461 | 3 565 | 3 678 | 3 805 | 3 949 | 4 106 | 4 270 | 4 434 | 4 588 | 4 721 | 4 831 | 4 918 | 4 979 | 5 017 | 5 035 |
| **64** | 3 202 | 3 306 | 3 407 | 3 510 | 3 620 | 3 744 | 3 885 | 4 039 | 4 199 | 4 359 | 4 509 | 4 639 | 4 747 | 4 831 | 4 891 | 4 926 |
| **65** | 3 044 | 3 149 | 3 251 | 3 351 | 3 452 | 3 560 | 3 682 | 3 819 | 3 970 | 4 126 | 4 283 | 4 430 | 4 557 | 4 662 | 4 745 | 4 802 |
| **66** | 2 894 | 2 991 | 3 094 | 3 195 | 3 293 | 3 392 | 3 498 | 3 617 | 3 752 | 3 900 | 4 053 | 4 207 | 4 350 | 4 475 | 4 577 | 4 657 |
| **67** | 2 760 | 2 840 | 2 935 | 3 037 | 3 136 | 3 233 | 3 330 | 3 434 | 3 551 | 3 683 | 3 828 | 3 978 | 4 129 | 4 270 | 4 391 | 4 491 |
| **68** | 2 647 | 2 704 | 2 783 | 2 877 | 2 977 | 3 075 | 3 170 | 3 265 | 3 367 | 3 482 | 3 612 | 3 754 | 3 901 | 4 049 | 4 187 | 4 306 |
| **69** | 2 553 | 2 588 | 2 644 | 2 722 | 2 815 | 2 914 | 3 010 | 3 103 | 3 197 | 3 297 | 3 410 | 3 538 | 3 677 | 3 822 | 3 966 | 4 101 |
| **70** | 2 474 | 2 491 | 2 526 | 2 582 | 2 659 | 2 750 | 2 847 | 2 941 | 3 033 | 3 125 | 3 224 | 3 335 | 3 460 | 3 597 | 3 739 | 3 880 |
| **71** | 2 393 | 2 407 | 2 425 | 2 460 | 2 516 | 2 592 | 2 682 | 2 777 | 2 870 | 2 960 | 3 051 | 3 148 | 3 257 | 3 380 | 3 514 | 3 652 |
| **72** | 2 299 | 2 323 | 2 337 | 2 356 | 2 391 | 2 446 | 2 521 | 2 610 | 2 703 | 2 795 | 2 883 | 2 973 | 3 068 | 3 175 | 3 295 | 3 427 |
| **73** | 2 182 | 2 224 | 2 248 | 2 264 | 2 283 | 2 319 | 2 373 | 2 447 | 2 534 | 2 626 | 2 716 | 2 803 | 2 891 | 2 985 | 3 089 | 3 207 |
| **74** | 2 043 | 2 104 | 2 146 | 2 171 | 2 188 | 2 207 | 2 243 | 2 297 | 2 370 | 2 455 | 2 545 | 2 633 | 2 719 | 2 805 | 2 897 | 3 000 |
| **75+** | 17 471 | 18 085 | 18 724 | 19 368 | 20 001 | 20 615 | 21 214 | 21 812 | 22 429 | 23 081 | 23 780 | 24 529 | 25 322 | 26 157 | 27 030 | 27 946 |

### A9.6 Numbers of males requiring treatment, by single age and year (2006-2021)

The table on the next page shows the projected number of males requiring treatment in Botswana by single year of age in each year from 2006 to 2021. Note that the "in need" population is defined as those with AIDS and not being treated less those who have discontinued, plus those who are receiving treatment

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 510 | 502 | 492 | 483 | 475 | 467 | 460 | 455 | 450 | 446 | 443 | 440 | 438 | 436 | 434 | 432 |
| **1** | 669 | 661 | 656 | 643 | 631 | 620 | 610 | 602 | 594 | 588 | 583 | 578 | 575 | 572 | 570 | 568 |
| **2** | 597 | 652 | 645 | 639 | 627 | 615 | 604 | 594 | 586 | 579 | 572 | 567 | 563 | 560 | 557 | 555 |
| **3** | 444 | 549 | 594 | 586 | 581 | 569 | 558 | 549 | 540 | 532 | 525 | 520 | 515 | 512 | 509 | 506 |
| **4** | 318 | 406 | 490 | 526 | 519 | 514 | 503 | 494 | 485 | 478 | 471 | 465 | 460 | 456 | 452 | 450 |
| **5** | 215 | 296 | 366 | 433 | 462 | 456 | 451 | 442 | 433 | 426 | 419 | 413 | 408 | 403 | 400 | 397 |
| **6** | 137 | 211 | 277 | 331 | 384 | 407 | 401 | 396 | 388 | 381 | 374 | 368 | 363 | 358 | 354 | 351 |
| **7** | 106 | 149 | 211 | 263 | 303 | 344 | 362 | 356 | 351 | 344 | 338 | 332 | 327 | 322 | 318 | 314 |
| **8** | 99 | 128 | 164 | 215 | 255 | 283 | 314 | 327 | 321 | 317 | 311 | 305 | 299 | 295 | 290 | 287 |
| **9** | 99 | 125 | 152 | 183 | 224 | 255 | 271 | 292 | 302 | 295 | 291 | 286 | 280 | 275 | 271 | 267 |
| **10** | 99 | 127 | 153 | 179 | 206 | 238 | 259 | 266 | 278 | 284 | 278 | 274 | 268 | 263 | 259 | 254 |
| **11** | 93 | 125 | 155 | 182 | 207 | 230 | 256 | 269 | 265 | 270 | 273 | 266 | 262 | 257 | 252 | 248 |
| **12** | 80 | 115 | 151 | 184 | 211 | 235 | 255 | 274 | 280 | 269 | 267 | 267 | 259 | 255 | 250 | 245 |
| **13** | 62 | 97 | 137 | 176 | 210 | 238 | 261 | 279 | 293 | 293 | 274 | 265 | 263 | 256 | 251 | 246 |
| **14** | 89 | 145 | 216 | 294 | 368 | 430 | 477 | 509 | 517 | 504 | 463 | 389 | 339 | 320 | 307 | 301 |
| **15** | 51 | 91 | 148 | 221 | 299 | 372 | 433 | 478 | 510 | 518 | 504 | 463 | 389 | 339 | 320 | 307 |
| **16** | 27 | 51 | 91 | 148 | 220 | 296 | 367 | 425 | 469 | 498 | 506 | 491 | 452 | 379 | 331 | 312 |
| **17** | 13 | 26 | 50 | 89 | 144 | 213 | 286 | 353 | 408 | 449 | 477 | 484 | 470 | 432 | 363 | 316 |
| **18** | 5 | 12 | 25 | 48 | 85 | 138 | 203 | 272 | 334 | 385 | 423 | 449 | 455 | 442 | 406 | 341 |
| **19** | 2 | 5 | 11 | 23 | 45 | 80 | 129 | 190 | 254 | 312 | 359 | 393 | 417 | 422 | 410 | 377 |
| **20** | 1 | 2 | 5 | 11 | 22 | 42 | 75 | 120 | 176 | 234 | 287 | 330 | 361 | 383 | 387 | 376 |
| **21** | 2 | 2 | 3 | 5 | 11 | 21 | 40 | 70 | 111 | 162 | 215 | 263 | 302 | 330 | 349 | 353 |
| **22** | 5 | 5 | 5 | 6 | 8 | 13 | 23 | 40 | 67 | 105 | 151 | 198 | 241 | 276 | 302 | 319 |
| **23** | 14 | 13 | 12 | 12 | 12 | 14 | 19 | 28 | 44 | 68 | 103 | 144 | 187 | 226 | 257 | 279 |
| **24** | 33 | 31 | 29 | 27 | 27 | 27 | 29 | 33 | 42 | 56 | 79 | 110 | 147 | 185 | 220 | 247 |
| **25** | 71 | 66 | 62 | 58 | 56 | 55 | 55 | 57 | 61 | 69 | 83 | 104 | 131 | 165 | 199 | 229 |
| **26** | 123 | 128 | 120 | 113 | 108 | 104 | 103 | 102 | 104 | 109 | 117 | 131 | 150 | 175 | 205 | 235 |
| **27** | 217 | 205 | 213 | 201 | 191 | 184 | 180 | 178 | 177 | 180 | 185 | 194 | 207 | 225 | 248 | 274 |
| **28** | 346 | 336 | 316 | 330 | 314 | 302 | 294 | 289 | 286 | 286 | 289 | 296 | 306 | 320 | 337 | 357 |
| **29** | 507 | 505 | 488 | 458 | 480 | 461 | 448 | 439 | 434 | 432 | 433 | 436 | 442 | 449 | 457 | 462 |
| **30** | 688 | 702 | 692 | 666 | 627 | 662 | 642 | 629 | 621 | 617 | 616 | 619 | 625 | 634 | 644 | 655 |
| **31** | 867 | 911 | 919 | 899 | 865 | 819 | 871 | 852 | 841 | 836 | 835 | 837 | 842 | 852 | 864 | 878 |
| **32** | 1 025 | 1 106 | 1 145 | 1 144 | 1 115 | 1 075 | 1 024 | 1 099 | 1 083 | 1 077 | 1 077 | 1 080 | 1 086 | 1 095 | 1 109 | 1 125 |
| **33** | 1 142 | 1 264 | 1 343 | 1 374 | 1 364 | 1 329 | 1 286 | 1 234 | 1 335 | 1 326 | 1 327 | 1 333 | 1 342 | 1 354 | 1 368 | 1 387 |
| **34** | 1 212 | 1 369 | 1 491 | 1 562 | 1 585 | 1 568 | 1 531 | 1 489 | 1 440 | 1 569 | 1 570 | 1 580 | 1 595 | 1 611 | 1 629 | 1 650 |
| **35** | 1 244 | 1 420 | 1 576 | 1 689 | 1 751 | 1 767 | 1 747 | 1 712 | 1 676 | 1 631 | 1 790 | 1 802 | 1 823 | 1 848 | 1 873 | 1 898 |
| **36** | 1 245 | 1 428 | 1 600 | 1 747 | 1 850 | 1 903 | 1 915 | 1 896 | 1 865 | 1 837 | 1 801 | 1 989 | 2 014 | 2 047 | 2 083 | 2 117 |
| **37** | 1 221 | 1 407 | 1 583 | 1 742 | 1 875 | 1 968 | 2 015 | 2 025 | 2 010 | 1 987 | 1 969 | 1 942 | 2 158 | 2 197 | 2 242 | 2 289 |
| **38** | 1 177 | 1 361 | 1 538 | 1 698 | 1 841 | 1 960 | 2 042 | 2 085 | 2 097 | 2 088 | 2 074 | 2 068 | 2 052 | 2 292 | 2 344 | 2 402 |
| **39** | 1 122 | 1 298 | 1 471 | 1 630 | 1 771 | 1 897 | 2 002 | 2 077 | 2 117 | 2 133 | 2 131 | 2 128 | 2 133 | 2 128 | 2 389 | 2 453 |
| **40** | 1 057 | 1 227 | 1 390 | 1 544 | 1 682 | 1 804 | 1 913 | 2 007 | 2 075 | 2 115 | 2 135 | 2 141 | 2 148 | 2 165 | 2 171 | 2 448 |
| **41** | 989 | 1 147 | 1 304 | 1 448 | 1 580 | 1 697 | 1 801 | 1 896 | 1 980 | 2 043 | 2 084 | 2 108 | 2 123 | 2 139 | 2 166 | 2 182 |
| **42** | 927 | 1 067 | 1 212 | 1 349 | 1 471 | 1 582 | 1 681 | 1 768 | 1 851 | 1 927 | 1 987 | 2 029 | 2 058 | 2 080 | 2 105 | 2 140 |
| **43** | 876 | 995 | 1 121 | 1 247 | 1 363 | 1 465 | 1 556 | 1 638 | 1 712 | 1 785 | 1 854 | 1 912 | 1 954 | 1 988 | 2 016 | 2 049 |
| **44** | 833 | 936 | 1 041 | 1 148 | 1 254 | 1 350 | 1 432 | 1 507 | 1 576 | 1 638 | 1 703 | 1 767 | 1 822 | 1 866 | 1 903 | 1 937 |
| **45** | 792 | 887 | 976 | 1 062 | 1 150 | 1 236 | 1 314 | 1 381 | 1 442 | 1 499 | 1 553 | 1 610 | 1 670 | 1 724 | 1 768 | 1 808 |
| **46** | 750 | 842 | 921 | 992 | 1 059 | 1 129 | 1 198 | 1 261 | 1 315 | 1 365 | 1 413 | 1 460 | 1 512 | 1 567 | 1 619 | 1 664 |
| **47** | 704 | 795 | 872 | 934 | 987 | 1 037 | 1 091 | 1 146 | 1 196 | 1 240 | 1 281 | 1 321 | 1 363 | 1 410 | 1 462 | 1 511 |
| **48** | 652 | 745 | 823 | 882 | 926 | 963 | 999 | 1 040 | 1 084 | 1 124 | 1 159 | 1 193 | 1 228 | 1 264 | 1 307 | 1 355 |
| **49** | 597 | 690 | 770 | 830 | 873 | 902 | 926 | 950 | 981 | 1 015 | 1 048 | 1 076 | 1 104 | 1 134 | 1 165 | 1 203 |
| **50** | 546 | 632 | 712 | 776 | 820 | 848 | 865 | 878 | 894 | 917 | 944 | 969 | 992 | 1 015 | 1 039 | 1 065 |
| **51** | 501 | 578 | 652 | 717 | 766 | 796 | 812 | 819 | 825 | 833 | 850 | 871 | 891 | 909 | 926 | 943 |
| **52** | 458 | 532 | 598 | 657 | 707 | 742 | 761 | 768 | 768 | 767 | 771 | 783 | 798 | 813 | 824 | 833 |
| **53** | 417 | 487 | 550 | 603 | 648 | 685 | 709 | 719 | 719 | 713 | 709 | 709 | 716 | 726 | 734 | 736 |
| **54** | 378 | 445 | 506 | 556 | 595 | 628 | 654 | 669 | 672 | 667 | 658 | 650 | 647 | 649 | 652 | 651 |
| **55** | 339 | 404 | 463 | 511 | 549 | 577 | 600 | 617 | 625 | 623 | 615 | 603 | 592 | 585 | 581 | 576 |
| **56** | 301 | 363 | 421 | 469 | 506 | 533 | 551 | 566 | 577 | 579 | 573 | 562 | 548 | 534 | 522 | 510 |
| **57** | 268 | 324 | 379 | 427 | 464 | 491 | 509 | 520 | 528 | 534 | 533 | 524 | 511 | 494 | 476 | 457 |
| **58** | 238 | 288 | 339 | 385 | 424 | 451 | 470 | 480 | 485 | 489 | 491 | 486 | 475 | 459 | 439 | 415 |
| **59** | 211 | 257 | 302 | 345 | 383 | 412 | 431 | 443 | 448 | 449 | 449 | 448 | 441 | 427 | 408 | 382 |
| **60** | 187 | 229 | 270 | 308 | 343 | 373 | 394 | 407 | 413 | 414 | 412 | 409 | 405 | 396 | 379 | 355 |
| **61** | 165 | 203 | 240 | 275 | 306 | 334 | 356 | 371 | 379 | 381 | 379 | 375 | 370 | 363 | 350 | 329 |
| **62** | 144 | 179 | 214 | 246 | 274 | 298 | 319 | 335 | 346 | 350 | 349 | 345 | 338 | 331 | 322 | 305 |
| **63** | 124 | 156 | 188 | 218 | 244 | 266 | 285 | 301 | 312 | 319 | 320 | 317 | 311 | 303 | 293 | 280 |
| **64** | 105 | 134 | 163 | 191 | 217 | 238 | 254 | 268 | 280 | 287 | 291 | 290 | 285 | 278 | 268 | 255 |
| **65** | 87 | 113 | 140 | 166 | 190 | 210 | 226 | 239 | 249 | 257 | 262 | 263 | 261 | 255 | 246 | 233 |
| **66** | 70 | 92 | 116 | 140 | 163 | 183 | 199 | 212 | 221 | 228 | 233 | 236 | 236 | 232 | 225 | 214 |
| **67** | 53 | 72 | 94 | 116 | 137 | 156 | 173 | 186 | 195 | 202 | 206 | 210 | 211 | 210 | 204 | 195 |
| **68** | 39 | 54 | 72 | 92 | 111 | 130 | 146 | 160 | 170 | 177 | 182 | 185 | 187 | 187 | 184 | 177 |
| **69** | 26 | 39 | 53 | 70 | 87 | 105 | 120 | 134 | 145 | 153 | 159 | 162 | 164 | 165 | 163 | 159 |
| **70** | 17 | 26 | 37 | 51 | 66 | 81 | 96 | 109 | 121 | 130 | 137 | 141 | 143 | 144 | 143 | 141 |
| **71** | 10 | 16 | 24 | 35 | 47 | 60 | 73 | 86 | 98 | 107 | 115 | 120 | 123 | 125 | 124 | 123 |
| **72** | 5 | 9 | 15 | 22 | 32 | 42 | 54 | 65 | 76 | 86 | 94 | 101 | 105 | 107 | 107 | 106 |
| **73** | 2 | 5 | 8 | 13 | 20 | 28 | 38 | 48 | 57 | 67 | 75 | 82 | 87 | 90 | 92 | 91 |
| **74** | 1 | 2 | 4 | 7 | 12 | 18 | 25 | 33 | 41 | 50 | 58 | 65 | 71 | 75 | 77 | 78 |
| **75+** | 1 | 1 | 3 | 6 | 12 | 21 | 33 | 49 | 70 | 95 | 123 | 153 | 183 | 213 | 240 | 262 |

### A9.7 Numbers of females requiring treatment, by single age and year (2006-2021)

The table on the next page shows the projected number of females requiring treatment in Botswana by single year of age in each year from 2006 to 2021. Note that the "in need" population is defined as those with AIDS and not being treated less those who have discontinued, plus those who are receiving treatment

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 504 | 496 | 486 | 477 | 469 | 461 | 455 | 449 | 444 | 440 | 437 | 434 | 432 | 430 | 428 | 427 |
| **1** | 662 | 654 | 649 | 636 | 624 | 613 | 603 | 595 | 587 | 581 | 576 | 572 | 568 | 565 | 563 | 561 |
| **2** | 591 | 645 | 638 | 633 | 620 | 608 | 597 | 588 | 579 | 572 | 566 | 561 | 557 | 553 | 551 | 548 |
| **3** | 440 | 543 | 587 | 580 | 575 | 563 | 552 | 543 | 534 | 526 | 519 | 514 | 509 | 506 | 503 | 500 |
| **4** | 315 | 402 | 485 | 521 | 514 | 508 | 498 | 489 | 480 | 472 | 465 | 459 | 455 | 451 | 447 | 445 |
| **5** | 213 | 293 | 362 | 429 | 458 | 451 | 446 | 437 | 429 | 421 | 414 | 408 | 403 | 399 | 395 | 392 |
| **6** | 136 | 209 | 274 | 327 | 380 | 403 | 396 | 392 | 384 | 377 | 370 | 364 | 359 | 354 | 350 | 347 |
| **7** | 105 | 148 | 209 | 260 | 300 | 341 | 358 | 352 | 348 | 341 | 334 | 328 | 323 | 318 | 314 | 311 |
| **8** | 98 | 126 | 163 | 213 | 253 | 280 | 310 | 324 | 318 | 313 | 307 | 301 | 296 | 291 | 287 | 283 |
| **9** | 98 | 123 | 150 | 181 | 222 | 252 | 268 | 289 | 298 | 292 | 288 | 282 | 277 | 272 | 268 | 264 |
| **10** | 98 | 125 | 151 | 177 | 203 | 236 | 256 | 263 | 275 | 281 | 274 | 270 | 265 | 260 | 256 | 251 |
| **11** | 92 | 123 | 153 | 180 | 204 | 227 | 252 | 265 | 262 | 267 | 270 | 263 | 259 | 254 | 249 | 245 |
| **12** | 79 | 114 | 149 | 181 | 208 | 232 | 252 | 271 | 277 | 265 | 263 | 263 | 256 | 252 | 247 | 242 |
| **13** | 61 | 96 | 135 | 174 | 207 | 235 | 258 | 275 | 289 | 289 | 270 | 262 | 260 | 252 | 248 | 243 |
| **14** | 88 | 143 | 213 | 290 | 363 | 424 | 471 | 502 | 511 | 497 | 457 | 384 | 334 | 316 | 303 | 297 |
| **15** | 51 | 89 | 146 | 218 | 295 | 367 | 427 | 472 | 503 | 511 | 497 | 457 | 384 | 334 | 315 | 303 |
| **16** | 26 | 50 | 89 | 146 | 217 | 292 | 362 | 420 | 463 | 492 | 499 | 485 | 446 | 374 | 326 | 308 |
| **17** | 13 | 27 | 50 | 88 | 143 | 211 | 283 | 349 | 404 | 444 | 471 | 478 | 464 | 427 | 359 | 312 |
| **18** | 11 | 17 | 29 | 51 | 88 | 140 | 204 | 271 | 333 | 384 | 421 | 446 | 452 | 439 | 404 | 340 |
| **19** | 21 | 22 | 28 | 39 | 59 | 93 | 141 | 201 | 263 | 320 | 366 | 400 | 423 | 428 | 416 | 384 |
| **20** | 53 | 51 | 51 | 55 | 64 | 82 | 112 | 156 | 209 | 266 | 317 | 359 | 390 | 410 | 415 | 404 |
| **21** | 121 | 116 | 112 | 109 | 110 | 116 | 131 | 157 | 195 | 243 | 293 | 338 | 375 | 403 | 421 | 425 |
| **22** | 239 | 233 | 224 | 216 | 209 | 206 | 208 | 219 | 241 | 273 | 314 | 357 | 397 | 429 | 453 | 469 |
| **23** | 411 | 411 | 402 | 388 | 375 | 363 | 356 | 354 | 361 | 377 | 403 | 437 | 473 | 507 | 534 | 554 |
| **24** | 630 | 648 | 647 | 633 | 614 | 595 | 579 | 567 | 562 | 565 | 575 | 595 | 622 | 651 | 678 | 701 |
| **25** | 876 | 924 | 944 | 940 | 923 | 899 | 876 | 856 | 841 | 832 | 833 | 838 | 852 | 872 | 894 | 915 |
| **26** | 1 094 | 1 210 | 1 264 | 1 286 | 1 281 | 1 261 | 1 235 | 1 209 | 1 187 | 1 169 | 1 160 | 1 159 | 1 161 | 1 169 | 1 183 | 1 199 |
| **27** | 1 331 | 1 439 | 1 574 | 1 631 | 1 653 | 1 650 | 1 630 | 1 604 | 1 578 | 1 555 | 1 538 | 1 529 | 1 529 | 1 530 | 1 534 | 1 542 |
| **28** | 1 521 | 1 681 | 1 793 | 1 941 | 2 000 | 2 025 | 2 025 | 2 008 | 1 984 | 1 960 | 1 940 | 1 927 | 1 921 | 1 924 | 1 924 | 1 926 |
| **29** | 1 660 | 1 854 | 2 020 | 2 130 | 2 286 | 2 347 | 2 377 | 2 382 | 2 372 | 2 353 | 2 333 | 2 318 | 2 308 | 2 304 | 2 305 | 2 294 |
| **30** | 1 741 | 1 964 | 2 163 | 2 325 | 2 427 | 2 591 | 2 654 | 2 690 | 2 703 | 2 700 | 2 689 | 2 678 | 2 670 | 2 669 | 2 673 | 2 681 |
| **31** | 1 764 | 2 010 | 2 234 | 2 425 | 2 577 | 2 670 | 2 839 | 2 906 | 2 948 | 2 971 | 2 978 | 2 977 | 2 975 | 2 977 | 2 986 | 3 000 |
| **32** | 1 735 | 1 995 | 2 239 | 2 451 | 2 627 | 2 767 | 2 851 | 3 024 | 3 094 | 3 144 | 3 176 | 3 194 | 3 204 | 3 213 | 3 227 | 3 246 |
| **33** | 1 666 | 1 930 | 2 184 | 2 412 | 2 606 | 2 764 | 2 892 | 2 968 | 3 142 | 3 216 | 3 274 | 3 316 | 3 345 | 3 366 | 3 386 | 3 411 |
| **34** | 1 574 | 1 830 | 2 085 | 2 320 | 2 526 | 2 698 | 2 839 | 2 954 | 3 022 | 3 197 | 3 274 | 3 339 | 3 391 | 3 430 | 3 462 | 3 494 |
| **35** | 1 476 | 1 712 | 1 956 | 2 190 | 2 400 | 2 581 | 2 731 | 2 855 | 2 958 | 3 020 | 3 194 | 3 274 | 3 345 | 3 406 | 3 455 | 3 498 |
| **36** | 1 383 | 1 595 | 1 817 | 2 038 | 2 245 | 2 427 | 2 584 | 2 713 | 2 821 | 2 914 | 2 971 | 3 141 | 3 225 | 3 301 | 3 369 | 3 427 |
| **37** | 1 298 | 1 489 | 1 684 | 1 882 | 2 075 | 2 253 | 2 408 | 2 541 | 2 652 | 2 746 | 2 830 | 2 883 | 3 049 | 3 134 | 3 214 | 3 288 |
| **38** | 1 223 | 1 394 | 1 567 | 1 737 | 1 906 | 2 070 | 2 221 | 2 351 | 2 463 | 2 557 | 2 639 | 2 715 | 2 764 | 2 925 | 3 011 | 3 095 |
| **39** | 1 155 | 1 311 | 1 463 | 1 611 | 1 753 | 1 894 | 2 031 | 2 156 | 2 264 | 2 357 | 2 437 | 2 508 | 2 577 | 2 624 | 2 779 | 2 865 |
| **40** | 1 088 | 1 235 | 1 373 | 1 501 | 1 622 | 1 737 | 1 851 | 1 963 | 2 065 | 2 154 | 2 232 | 2 299 | 2 362 | 2 425 | 2 469 | 2 618 |
| **41** | 1 022 | 1 162 | 1 291 | 1 405 | 1 508 | 1 603 | 1 693 | 1 784 | 1 874 | 1 957 | 2 029 | 2 094 | 2 151 | 2 207 | 2 264 | 2 307 |
| **42** | 955 | 1 088 | 1 211 | 1 318 | 1 408 | 1 487 | 1 559 | 1 628 | 1 698 | 1 770 | 1 836 | 1 895 | 1 949 | 1 998 | 2 047 | 2 100 |
| **43** | 887 | 1 014 | 1 131 | 1 233 | 1 317 | 1 385 | 1 443 | 1 495 | 1 546 | 1 600 | 1 656 | 1 709 | 1 757 | 1 802 | 1 844 | 1 888 |
| **44** | 818 | 940 | 1 052 | 1 149 | 1 229 | 1 292 | 1 340 | 1 380 | 1 417 | 1 453 | 1 493 | 1 537 | 1 579 | 1 617 | 1 654 | 1 689 |
| **45** | 749 | 866 | 972 | 1 064 | 1 141 | 1 201 | 1 246 | 1 279 | 1 305 | 1 328 | 1 353 | 1 382 | 1 415 | 1 447 | 1 476 | 1 503 |
| **46** | 679 | 792 | 894 | 982 | 1 054 | 1 112 | 1 156 | 1 186 | 1 206 | 1 220 | 1 234 | 1 249 | 1 268 | 1 290 | 1 311 | 1 327 |
| **47** | 609 | 719 | 818 | 902 | 970 | 1 025 | 1 066 | 1 096 | 1 115 | 1 125 | 1 130 | 1 136 | 1 142 | 1 151 | 1 160 | 1 166 |
| **48** | 538 | 645 | 742 | 823 | 889 | 941 | 980 | 1 008 | 1 027 | 1 037 | 1 039 | 1 037 | 1 035 | 1 031 | 1 027 | 1 020 |
| **49** | 468 | 571 | 666 | 747 | 811 | 860 | 897 | 924 | 943 | 953 | 955 | 951 | 942 | 930 | 914 | 895 |
| **50** | 400 | 498 | 591 | 671 | 735 | 784 | 819 | 845 | 862 | 872 | 876 | 872 | 861 | 844 | 821 | 792 |
| **51** | 336 | 427 | 516 | 596 | 661 | 711 | 746 | 770 | 786 | 796 | 800 | 797 | 787 | 769 | 742 | 707 |
| **52** | 278 | 360 | 444 | 522 | 588 | 639 | 676 | 700 | 716 | 724 | 728 | 726 | 718 | 701 | 674 | 637 |
| **53** | 226 | 299 | 376 | 451 | 516 | 569 | 608 | 635 | 650 | 659 | 662 | 660 | 654 | 639 | 615 | 578 |
| **54** | 181 | 244 | 313 | 383 | 447 | 501 | 542 | 571 | 589 | 598 | 601 | 600 | 594 | 581 | 560 | 528 |
| **55** | 143 | 197 | 257 | 320 | 381 | 434 | 478 | 510 | 531 | 542 | 546 | 544 | 539 | 528 | 510 | 482 |
| **56** | 112 | 156 | 207 | 263 | 319 | 371 | 416 | 450 | 474 | 488 | 494 | 494 | 489 | 479 | 462 | 437 |
| **57** | 88 | 123 | 165 | 213 | 263 | 312 | 356 | 392 | 419 | 437 | 445 | 447 | 443 | 434 | 419 | 396 |
| **58** | 69 | 97 | 131 | 171 | 214 | 258 | 300 | 337 | 366 | 386 | 399 | 403 | 401 | 393 | 380 | 359 |
| **59** | 54 | 76 | 103 | 136 | 172 | 211 | 249 | 284 | 314 | 338 | 353 | 361 | 362 | 356 | 344 | 325 |
| **60** | 44 | 61 | 82 | 108 | 137 | 170 | 204 | 237 | 266 | 291 | 309 | 320 | 324 | 322 | 312 | 296 |
| **61** | 35 | 49 | 65 | 86 | 109 | 136 | 165 | 194 | 222 | 247 | 267 | 280 | 288 | 289 | 283 | 269 |
| **62** | 28 | 39 | 53 | 69 | 87 | 109 | 132 | 157 | 183 | 206 | 226 | 242 | 253 | 257 | 254 | 244 |
| **63** | 23 | 32 | 43 | 55 | 70 | 87 | 106 | 127 | 148 | 170 | 189 | 206 | 218 | 225 | 226 | 220 |
| **64** | 18 | 25 | 34 | 44 | 56 | 70 | 85 | 101 | 119 | 138 | 156 | 173 | 186 | 195 | 199 | 197 |
| **65** | 14 | 20 | 27 | 35 | 45 | 56 | 68 | 81 | 96 | 111 | 127 | 142 | 156 | 166 | 173 | 174 |
| **66** | 11 | 15 | 21 | 28 | 36 | 44 | 54 | 65 | 76 | 89 | 102 | 116 | 129 | 139 | 147 | 151 |
| **67** | 8 | 11 | 16 | 21 | 28 | 35 | 43 | 51 | 61 | 71 | 82 | 93 | 104 | 115 | 123 | 129 |
| **68** | 5 | 8 | 11 | 16 | 21 | 27 | 33 | 40 | 48 | 56 | 65 | 74 | 84 | 93 | 102 | 108 |
| **69** | 3 | 5 | 8 | 11 | 15 | 20 | 25 | 31 | 37 | 44 | 51 | 58 | 66 | 74 | 82 | 89 |
| **70** | 2 | 3 | 5 | 7 | 10 | 14 | 18 | 23 | 28 | 34 | 39 | 46 | 52 | 59 | 65 | 72 |
| **71** | 1 | 2 | 3 | 5 | 7 | 10 | 13 | 17 | 21 | 25 | 30 | 35 | 40 | 46 | 52 | 57 |
| **72** | 1 | 1 | 2 | 3 | 4 | 6 | 9 | 12 | 15 | 19 | 23 | 27 | 31 | 36 | 40 | 45 |
| **73** | 0 | 1 | 1 | 2 | 3 | 4 | 6 | 8 | 10 | 13 | 16 | 20 | 23 | 27 | 31 | 35 |
| **74** | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 5 | 7 | 9 | 12 | 14 | 17 | 20 | 23 | 27 |
| **75+** | 0 | 0 | 0 | 1 | 1 | 3 | 4 | 7 | 10 | 15 | 21 | 28 | 36 | 46 | 56 | 68 |