Cost-Benefit Analysis of the Initiative to Accelerate the Digitizing of 7.5-Minute Maps

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Contents

Tables

Figures

EXECUTIVE SUMMARY

The initiative to accelerate the collection of base cartographic data would allow complete digitization of the U.S. Geological Survey (USGS) 1:24,000-scale 7.5-minute primary map series by fiscal year 2000. At present 9.5 percent of the map series has been digitized. Without the initiative, at current production rates, less than 25 percent of the map series will be digitized by 2000.

The initiative would run for 7 years and a total of $308.8 million would have to be spent to digitize the primary map series. Using a discount rate of 7 percent, the present value of this cost is $233.8 million.

It is estimated that, by accelerating the digitization of the primary map series, total benefits of about $750 million would be generated over the 7-year life of the initiative, with a present value of almost $550 million. Benefits exceed the cost every year except the first. The net present value of this portion of the initiative is over $300 million, and its benefit to cost ratio is 2.3 to 1. Implementation would result in a net cost saving to Federal agencies of over $400 million through fiscal year 2000.

Two major things happen to reduce costs when additional primary map data are added to the National Digital Cartographic Data Base (NDCDB). First, some current geographic information system (GIS) users who now independently digitize from USGS graphic maps no longer need to do so, because the digital data they need would be available from the NDCDB. This reduces the amount of duplicate digitizing. Second, some applications that are now too expensive to conduct with GIS technology would become feasible because of the availability of low-cost digital data from the NDCDB. The use of GIS technology provides a cost saving over manual methods currently used to perform the same tasks.

It is estimated that $18 million of duplicate digitizing would be eliminated and that a 70 percentage-point increase in the number of GIS applications in Federal agencies would be supported by the initiative. The great bulk of the measured cost saving comes from

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these new GIS applications; that is, from tasks currently being done manually that can be accomplished at a lower cost using GIS technology.

There are positive net benefits from the initiative even if it is funded at levels significantly lower than planned. Figure 1 shows that the net present value of the initiative increases steadily as the level of funding increases. The greatest net present value occurs when the initiative is fully funded.

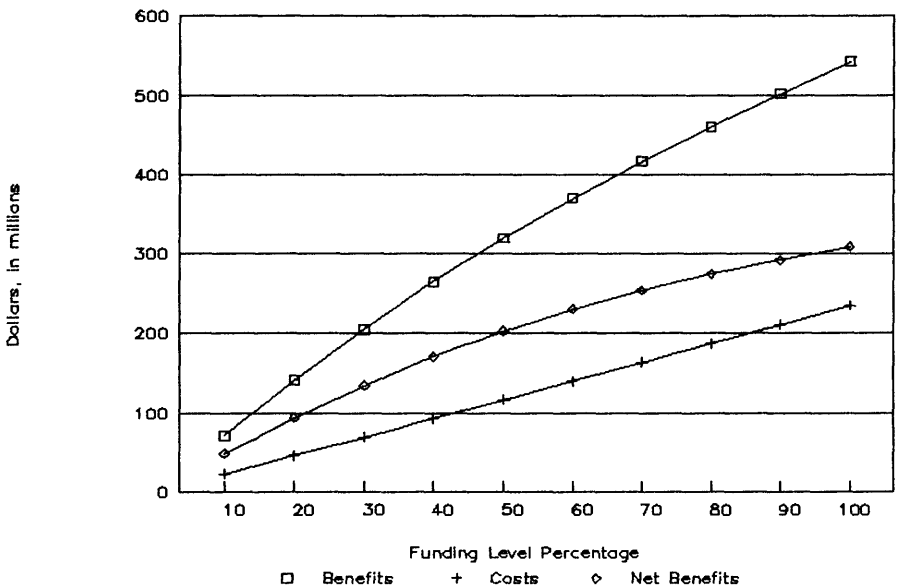

Figure 1. Discounted value of initiative -- at various funding levels.

Most of the information used to derive benefit estimates comes from the Digital Benefits Study, research the USGS is conducting to determine the value of having base cartographic data in digital form. The number of new GIS applications supported by the addition of more primary map data to the NDCDB is estimated from the current use of NDCDB digital data documented in a survey of 67 Federal GIS applications. The estimate of cost saving generated by the new applications is based on the estimated value of cost saving generated by the surveyed GIS applications. Sensitivity testing indicates that the initiative would be found to be cost effective under a wide range of different assumptions.

The analysis considers only the benefits of the reduced cost generated by Federal GIS users. The analysis does not consider the benefits of improving the quality of output and the benefits generated by State and local government GIS users. This means that the benefit estimates are conservative. Including non-Federal GIS users and other types of GIS benefits would significantly increase the measured value of the data produced from the initiative.

In addition to the benefits cited in this report, implementing the initiative would complement existing programs such as USGS Mapping Partnerships and the Department of the Interior Digitizing Contract by channeling new projects to the digitizing industry, creating new jobs, and stimulating growth and investment in GIS technology.

COST-BENEFIT ANALYSIS OF THE INITIATIVE TO ACCELERATE THE DIGITIZING OF 7.5-MINUTE MAPS

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1. Introduction

The multiagency initiative to accelerate the collection of base cartographic data is intended to develop a national digital base cartographic infrastructure for the effective use of geographic information system (GIS) technologies by Federal and State agencies. A major component of the initiative is to complete digitization of the U.S. Geological Survey (USGS) 1:24,000-scale primary map series by fiscal year 2000. At present only 9.5 percent of the map series has been digitized. At the current production rate less than 25 percent of the map series will be digitized by 2000.

Graphic 1:24,000-scale maps are the standard base used by most Federal agencies for manual (that is, non-GIS) applications. Digitized features from the 1:24,000-scale map series form the framework most Federal agencies use for GIS applications. Because the USGS has not digitized the bulk of these maps, Federal agencies are independently digitizing the graphic maps needed for their specific applications, which leads to duplication of effort. The lack of complete digital coverage from the USGS raises the cost of GIS applications. This reduces the net benefits of current GIS applications and discourages the use of GIS technology on other potentially valuable applications.

This report estimates the magnitude of these effects and compares the cost and benefits of completing digitization of the USGS primary map series by the year 2000.

Notes:

1. The report focuses on the *direct* effects of accelerating the digitizing of the USGS primary map series. Because the initiative would interact with existing programs such as USGS Mapping Partnerships, it would also have *indirect* effects on the economy and job creation. See section 12 (Economic Stimulus Effects) for a discussion of this.

2. The initiative to accelerate the collection of base cartographic data involves numerous components in addition to the digitization of the USGS primary

map series. These include the production of digital orthophotos, a 5-year cycle of aerial photography, and several other interagency initiatives (for example, digitizing nautical chart information). However, in this report, the term "initiative" refers only to digitization of the USGS primary map series.

2. Methodology

The approach is to compare what would happen with the initiative to what would happen without the initiative. The initiative will allow the USGS to accelerate the population of the National Digital Cartographic Data Base (NDCDB) with digital line graphs (DLG) from the 1:24,000-scale maps. The percentage of the NDCDB that is complete is defined as the percentage of DLG's entered into the NDCDB.

An increase in the amount of DLG data in the NDCDB has three effects on GIS users.

1. Some current GIS users who independently digitize from USGS graphic maps no longer need to do so because the digital data they need would be available from the NDCDB. This reduces duplicate digitizing and lowers the cost for these users.

2. Some current GIS users who use some other type of base cartographic data (for example, data at 1:100,000 scale) would use DLG's from the NDCDB instead. Although this does not necessarily reduce the cost for the users, it almost certainly improves the output of their GIS applications. The improvement comes both from the use of larger scale base data and from the higher quality (national map accuracy standards) of USGS digital data.

3. Some applications that are now too expensive to conduct with GIS technology would be feasible because of the availability of low-cost digital data from the NDCDB. Adding DLG's to the NDCDB encourages the growth of GIS applications.

The task is to measure the results of these three effects. This is done in a five-step process.

1. Measure, by year, what percent of the NDCDB would be complete without the initiative. That is, measure the current number of DLG's in the NDCDB and identify the current production rate of DLG's.

2. Measure, by year, what percent of the NDCDB would be complete with the initiative. The initiative provides a complete NDCDB by fiscal year 2000.

3. Estimate how much duplicate digitizing is presently being done by other Federal agencies. This will decline to near zero as the NDCDB nears completion.

4. Estimate how many manual applications will switch to the use of GIS technology because of the availability of low-cost digital base cartographic data

from the NDCDB.

5. Estimate the value of the new GIS applications counted in step four. The value is defined as the difference in the cost of performing these applications with and without GIS technology.

The strength of the three effects determines the benefits of accelerating the production of DLG's. These benefits are then compared against the cost of the initiative to determine the net benefits and the benefit to cost ratio for the initiative.

Notes:

1. The NDCDB contains numerous data types in addition to 1:24,000-scale DLG's. It also contains 1:100,000-scale DLG's, digital elevation model (DEM) data sets, and digital orthophotoquads. However, in this report, only 1:24,000-scale DLG data in the NDCDB are discussed.

2. The analysis attempts to isolate the effect of adding DLG's to the NDCDB. To do this it is assumed that all other factors affecting the use of GIS technology remain constant. Because the number of DLG's in the NDCDB is the only factor that is allowed to change, any change in GIS use is caused by the preceding change in the NDCDB.

   The factors assumed to be constant are:
   a. Investment in GIS technology
      - That is, the analysis assumes there will be no increase in the current level of GIS hardware and software, physical facilities, or GIS support staff.
   b. GIS technology
      - That is, the analysis assumes there will be no improvement in GIS software or hardware.
   c. Demand for GIS
      - That is, the analysis assumes there will be no increase in GIS use other than that caused by the addition of DLG's to the NDCDB.

   The assumption that these factors will remain constant over the 7-year initiative is unrealistic. All three factors show a strong upward trend (that is, more investment, better technology, and greater demand). However, the trend in all cases works to increase the value of adding DLG's to the NDCDB. This means that the analysis is conservative.

3. The analysis relies on information developed during the Digital Benefits Study. The Digital Benefits Study is an ongoing USGS research project to determine

the value of digital base cartographic data and the use of GIS technology in the Federal Government. The first phase of the study involved a series of more than 60 case studies of successful Federal GIS applications. These case studies established techniques for measuring the benefits of GIS use and identified factors that influence the level of benefits. The results were generalized by the digital benefits model, a pair of equations that predict GIS benefit levels. The digital benefits model was used to estimate the benefits of GIS use in the Federal Government. See appendix A for a description of this research.

3. Effect of the Initiative

a. Percent of the NDCDB complete without the initiative

There are nine separate DLG categories in the NDCDB.

1. Public Land Survey System (PLSS)
2. Boundaries
3. Hydrography (lakes/streams)
4. Transportation
5. Manmade features (MMF)
6. Geodetic control data
7. Vegetation cover
8. Nonvegetated cover
9. Hypsography (elevation contours)

There are approximately 54,000 7.5-minute quadrangles in the conterminous United States and Hawaii. Some of those maps are offset from the standard quadrangle position, whereas the digital files are collected in standard position. Therefore, some of the 54,000 maps are represented by two to four digital cells (standard-position quadrangles). Providing complete data sets for the lower 49 States means producing those sets for approximately 58,000 cells.

The PLSS does not exist in all parts of the country. Complete coverage for the PLSS requires approximately 40,000 DLG's.

The total number of DLG's required for complete coverage of all nine categories is about 504,000. Table 1 shows the number of files of each category in the NDCDB at the end of fiscal year 1992.

Table 1. Percentage of the NDCDB completed as of the end of FY 1992

	DLG's completed	
Category	Number	Percent
PLSS	13,339	33.3
Boundary	16,161	27.9
Hydro.	5,932	10.2
Trans.	5,916	10.2
MMF	1,177	2.0
Control	1,235	2.1
Veg.	1,240	2.1
Nonveg.	1,225	2.1
Hypso.	1,855	3.2
Total	48,080	9.5

Table 2 shows the cumulative percent of DLG's of each category that will be complete each year through fiscal year 2000, given current and planned expenditures (that is, in the absence of the initiative). The projections are based on USGS estimates of production rates for each DLG category. See appendix B for a discussion of how the projections were made.

Table 2. Percent of DLG's complete without the initiative

	Percent of DLG's complete without the initiative							
Category	1993	1994	1995	1996	1997	1998	1999	2000
PLSS	35.3	37.3	39.1	41.0	42.8	44.7	46.5	48.1
Boundary	29.5	31.1	32.8	34.4	36.0	37.5	38.9	40.2
Hydro.	12.1	13.8	15.5	17.3	19.0	20.5	22.0	23.3
Trans.	11.5	13.2	15.0	16.7	18.4	19.9	21.4	22.8
MMF	2.7	4.5	6.4	8.3	10.0	11.7	13.5	15.1
Control	2.7	4.6	6.4	8.3	10.1	11.8	13.5	15.1
Veg.	2.8	4.6	6.4	8.3	10.1	11.8	13.5	15.2
Nonveg.	2.7	4.6	6.4	8.3	10.1	11.8	13.5	15.1
Hypso.	4.0	5.8	7.7	9.6	11.3	13.0	14.8	16.4
Total	10.6	12.4	14.2	16.0	17.8	19.4	21.1	22.6

b. Percent of the NDCDB complete with the initiative

The funds provided by the initiative will allow the digitization of all DLG's by fiscal year 2000. Table 3 shows the cumulative percent of DLG's of each category that will be complete each year using these new funds.

The projections are based on the assumption that an equal proportion of each DLG category will be digitized each year, and that the total DLG production is proportional to the new funds provided for digitizing each year. See appendix B for a discussion of how the projections were made.

Table 3. Percent of DLG's complete with the initiative

	Percent of DLG's in the NDCDB by end of fiscal year						
Category	1994	1995	1996	1997	1998	1999	2000
PLSS	44.0	52.5	60.9	69.1	78.5	88.8	100.0
Boundary	38.9	48.2	57.3	66.2	76.5	87.6	100.0
Hydro.	23.8	35.3	46.7	57.7	70.4	84.4	100.0
Trans.	23.3	34.9	46.3	57.4	70.2	84.3	100.0
MMF	15.6	28.3	40.8	53.0	67.0	82.6	100.0
Control	15.6	28.3	40.8	53.0	67.0	82.6	100.0
Veg.	15.6	28.3	40.8	53.0	67.1	82.6	100.0
Nonveg.	15.6	28.3	40.8	53.0	67.0	82.6	100.0
Hypso.	16.7	29.2	41.6	53.6	67.5	82.9	100.0
Total	22.5	34.2	45.7	56.9	69.9	84.1	100.0

Table 4 compares the percent of total DLG's that will be complete in the absence of the initiative with the percent that will be complete with the initiative.

Table 4. Percent of the NDCDB complete, with and without the initiative

	1994	1995	1996	1997	1998	1999	2000
Without initiative	12.4	14.2	16.0	17.8	19.4	21.1	22.6
With initiative	22.5	34.2	45.7	56.9	69.9	84.1	100.0

Percent of DLG's complete is not the only way to measure the NDCDB. See appendix C for the definition and calculation of two alternative measures.

4. Cost of the Initiative

The initiative proposes to add new funds for digitization; that is, funds above the planned expenditures on digitization (see table 5).

Table 5. Cost of the initiative (millions of dollars)

	1994	1995	1996	1997	1998	1999	2000	Total
New funds	40.3	39.4	38.6	37.8	45.1	50.4	57.2	308.8

5. Reduction of Duplicate Digitizing

One effect of adding DLG's to the NDCDB is a reduction in the amount of duplicate digitizing by other Federal agencies. That is, some GIS users who previously would have independently digitized data from USGS maps will get the base digital data they need from the NDCDB instead. The cost saving from a reduction in duplicate digitizing depends on the amount of duplicate digitizing currently being done.

It is not known how much other Federal agencies are spending on the duplicate digitizing of base cartographic data. However, it is probable that such expenditures amount to many millions of dollars. A 1982 General Accounting Office report on duplicate digitizing found potential savings of $4.5 million at just the Bureau of Land Management and the Bureau of the Census. Federal requirements for base digital data are many times higher now than in 1982, and the NDCDB is still only 9.5 percent complete. Annual requests for base digital data collected by the OMB Circular A-16 process cannot be filled by current USGS production capacity. Requirements for base digital data that are not met by the USGS result either in duplicate digitizing or in uncompleted projects. More than one-third of the GIS applications studied in the Digital Benefits Study involved the use of 1:24,000-scale base data that had not yet been digitized by the USGS.

No studies have been done that measure the total amount of duplicate digitizing being done by other Federal agencies. However, it is possible to estimate these expenses.

The October 26, 1992, issue of "Government Computer News" reports that the Federal Government spent over $900 million on GIS purchases in 1992. It is acknowledged within the GIS community that about 75 percent of the cost of developing and running a GIS installation are for obtaining and maintaining digital data (see, for example, Aronoff, 1989, p. 9 and 42). This implies current annual Federal expenditures of about $675 million on digital data. (75 percent x $900 million = $675 million).

What portion of this $675 million is spent on base categories of digital data? No studies have been done that directly address this question, but the experience of the Bureau of Indian Affairs (BIA) suggests that only a small portion of the $675 million is being spent on base categories of data. In September 1988 the BIA issued a cost and benefit analysis of the implementation of GIS's in 16 BIA agency offices. The BIA report lists all of the data themes, both base and thematic, digitized for each office (a total of 63 base themes and 67 nonbase themes).

By mid-1991 the same 16 BIA offices had a total of 82 base themes and 236 nonbase themes. This is an increase of 19 base themes and 169 nonbase themes. Excluding the three offices with the least developed GIS installations in 1988, the increase is 10

base themes and 152 nonbase themes in the other 13 offices. This indicates that once beyond an initial implementation period, when a large portion of data collection concerns base data, the great majority of data themes collected are thematic (nonbase). According to the BIA experience, only about 6 percent of the data themes collected are base. (10 base themes ÷ 162 total themes = 6% base themes).

It is not known if the BIA experience is typical of that for other Federal agencies. However, an Indian reservation is a microcosm of the larger society, and the management tasks of a BIA office parallel many of the wider responsibilities of other Federal agencies. If any single agency can be said to represent the entire range of Federal GIS activities, it is probably the BIA.

The 1988 BIA analysis also reports digitizing costs by theme. Across all themes the average nonbase theme costs 2.25 times as much as the average base theme. If this cost ratio is typical, then the portion of the $675 million being spent on digitizing base data can be estimated at $18 million. ($675 million x 6 percent ÷ 2.25 = $18 million).

This figure is an estimate of current annual expenditures on duplicate digitizing of base cartographic data; that is, when the NDCDB is 9.5 percent complete. As more DLG's are added to the NDCDB, the amount of duplicate digitizing will decline. Table 6 shows the estimated decline in duplicate digitizing each of the 7 years of the initiative. The table assumes a proportionate reduction in duplicate digitizing for each percent addition of DLG's to the NDCDB above the current level of 9.5 percent.

Table 6. Reduction in duplicate digitizing, with and without the initiative (in millions of dollars)

	1994	1995	1996	1997	1998	1999	2000
Without initiative	0.6	0.9	1.3	1.6	2.0	2.3	2.6
With initiative	2.6	4.9	7.2	9.4	12.0	14.8	18.0

6. Increase in the Number of GIS Applications

One effect of the addition of newly digitized DLG's to the NDCDB is an increase in the number of tasks to which it is cost effective to apply GIS technology. That is, tasks that would be too expensive if the user had to independently digitize base themes become feasible because of the availability of low-cost digital data from the NDCDB. No study has been done that directly answers the question of how many new GIS applications would be encouraged by the addition of DLG's to the NDCDB. However, an estimate can be made using information collected in the Digital Benefits Study.

A total of 67 Federal GIS applications were examined in the Digital Benefits Study. The applications can be classified according to the likelihood that they would use available DLG's from the NDCDB. There are four possibilities.

1. Current use: The application currently uses 1:24,000-scale DLG data from the NDCDB.

2. Likely use: The application currently uses 1:24,000-scale base data, but not from the NDCDB. The application almost certainly would use DLG's from the NDCDB if they were available.

3. Potential use: The application does not currently use 1:24,000-scale base data, but could be modified to use 1:24,000-scale DLG's if they were available. For example, an application currently using 1:100,000-scale base data or DEM's.

4. No potential use: The application does not currently use 1:24,000-scale base data and would not use DLG's even if they were available. For example, applications offshore or in foreign countries for which even a complete NDCDB would have no use.

Table 7 shows the classification of the 67 test applications into these four categories.

Table 7. Current use of USGS base data

	Test applications	
Category	Number	Percent
Current use	9	13.5
Likely use	24	36
Potential use	15	22.5
No potential use	19	28
Total	67	100

The NDCDB is 9.5 percent complete. This means that 9.5 percent of the DLG's are supporting 13.5 percent of the GIS applications. Assuming that each additional percent completion of the NDCDB will support applications in this same ratio of 13.5 to 9.5, then it is possible to estimate the number of new GIS applications that would develop in response to the increased availability of low-cost digital base data from the NDCDB.

Some of the increase in the number of applications in the current-use category will come from current applications in the likely-use and potential-use categories. With more DLG's available from the NDCDB, some of these current applications will start using DLG's from the NDCDB. Some of the increase will be from applications that did not previously use GIS technology. The availability of low-cost base data from the NDCDB lowers the costs of GIS use and makes these applications feasible.

Table 8 shows the change in the percent of applications in each category as DLG's are added to the NDCDB.

Table 8. Changing use of USGS base data

Percent of NDCDB completed	Percent of current applications					
	No potential use	Potential use	Likely use	Current use		
				Shifted	New to GIS	Total
9.5	28	22.5	36	-	-	13.5
20	28	19.9	31.8	6.8	8.1	28.4
30	28	17.4	27.8	13.3	15.8	42.6
40	28	14.9	23.9	19.7	23.6	56.8
50	28	12.4	19.9	26.2	31.4	71.1
60	28	9.9	15.9	32.7	39.1	85.3
70	28	7.5	11.9	39.1	46.9	99.5
80	28	5.0	8	45.5	54.7	113.7
90	28	2.5	4	52.0	62.4	127.9
100	28	0	0	58.5	70.1	142.1

All of the percentages are interpreted as percentage points of the total number of current applications; that is, of the level of GIS use when the NDCDB is 9.5 percent complete.

a. The no-potential-use applications are a constant 28 percentage points. This category of applications is unaffected by the number of DLG's in the NDCDB.

b. The potential-use and likely-use categories start at 22.5 percentage points and 36 percentage points respectively and progressively dwindle to zero percentage points

when the NDCDB is complete. The total percentage point shift from these categories to the current-use category is shown in the column labeled "Shifted."

The potential use entries are given by the formula:

22.5 - (Percent of NDCDB completed - 9.5) * (22.5/90.5)

For example, when the NDCDB is 30 percent complete:

Potential use = 22.5 (20 - 9.5) * (22.5/90.5)
= 22.5 - (20.5) * (0.2486)
= 22.5 - 5.1
Potential use = 17.4

The likely use entries are given by the formula:

36 - (Percent of NDCDB completed - 9.5) * (36/90.5)

For example, when the NDCDB is 80 percent complete:

Likely use = 36 - (80 - 9.5) * (36/90.5)
= 36 - (70.5) * (0.3978)
= 36 - 28
Likely use = 8

c. The current-use category is divided into three parts:

1. "Shifted" is the percentage point total of existing GIS applications that will start to use DLG's from the NDCDB as more DLG's are added to the NDCDB.

   The "Shifted" entries are given by the formula:

   58.5 - Potential use - Likely use

   For example, when the NDCDB is 50 percent complete:

   Shifted = 58.5 - 12.4 - 19.9
   Shifted = 26.2

2. "New to GIS" is the percentage point total of applications currently being run with non-GIS techniques that will switch to the use of GIS technology as more DLG's are added to the NDCDB.

   The "New to GIS" entries are given by the formula:

   Total - 13.5 - Shifted

   For example, when the NDCDB is 20 percent complete:

   New to GIS = 28.4 - 13.5 - 6.8
   New to GIS = 8.1

3. "Total" is the percentage point total of applications using DLG's from the NDCDB. It is the sum of the shifted and new to GIS percentage points, plus the original 13.5 percentage points of current use when the NDCDB is 9.5-percent complete.

   The "Total" entries are given by the formula:
   Percent of NDCDB completed * (13.5/9.5)

   For example, when the NDCDB is 60 percent complete:
   Total = 60 * (13.5/9.5)
   Total = 85.3

All three of these current-use percentage point values steadily increase as more DLG's are added to the NDCDB.

When the NDCDB is complete, the "New to GIS" total has increased to 70.1 percentage points. This says that the availability of low-cost digital base cartographic data from a complete NDCDB would encourage a 70.1 percent increase in the use of GIS technology.

The percentage increase in applications using 1:24,000-scale DLG's from the NDCDB is even greater. The "New to GIS" total of 70.1 percentage points is 5.2 times as large as the 13.5 percentage points of GIS applications currently using DLG's from the NDCDB.

7. Value of Increased GIS Applications

It is estimated that the completion of the NDCDB will encourage the development of 70 percent more GIS applications. These are all applications where the use of GIS technology reduces the cost of performing some task previously done by manual (non-GIS) methods.

Table 9 shows the estimated increase in GIS applications through fiscal year 2000. The increase is much larger with the initiative because the initiative leads to the addition of many more DLG's to the NDCDB.

Table 9. New GIS applications

	Percent of new applications in fiscal year						
	1994	1995	1996	1997	1998	1999	2000
Without initiative	2.3	3.7	5.1	6.4	7.7	9.0	10.2
With initiative	10.1	19.1	28.0	36.7	46.8	57.8	70.1

How much will Federal agencies save because of these additional uses of GIS technology? The simplest answer is to assume that the average cost saving from the new GIS applications is equal to the average cost saving from the current GIS applications. Total cost saving from the current GIS applications is estimated at about $450 million. This means that each 1-percent increase in the number of applications saves $4.5 million.

Using this simple approach, the estimated cost saving from the new applications is calculated by multiplying the percentage-point increase in new applications times the average cost saving of $4.5 million. Table 10 shows the estimated cost saving from the new applications.

Table 10. Cost saving from new applications (simple version)
(in millions of dollars)

	1994	1995	1996	1997	1998	1999	2000
Without initiative	10.1	16.4	22.8	28.9	34.6	40.3	45.7
With initiative	45.3	86.1	126.2	165.3	210.4	260.1	315.5

Net present value of cost saving = $721.9

There are problems with this simple approach to estimating the cost saving from the new GIS applications.

First, this approach may underestimate the average cost saving of the additional

applications. This is because some applications require coverage of large areas (entire States or regions, or the entire country). If an incomplete NDCDB provides coverage of only a portion of the needed area, the user may incur higher per unit costs because of the difficulty of integrating data from different sources. It is only when the NDCDB provides coverage of all of the needed area that data costs fall enough to justify the use of GIS technology. This agglomerative effect implies that average cost saving may rise as the NDCDB nears completion.

Two factors act to offset this rise in average cost saving. The first is that the USGS attempts to prioritize the production of DLG's so that those DLG's of most value to users are produced first. A principle purpose of the OMB Circular A-16 process is to help the USGS do this. To the extent that the USGS is successful in understanding Federal requirements, the average cost saving of new GIS applications will decline as DLG's are added to the NDCDB.

The final factor is prioritizing done by the Federal GIS users themselves. With limited resources, Federal agencies will tend to apply GIS technology to its most productive applications. All other things being equal, the average cost saving is likely to be higher on current applications than on the new applications encouraged by the addition of DLG's to the NDCDB. After all, the users could have digitized the base data themselves rather than wait for them to be available through the NDCDB (this in fact was done for many current GIS applications). The fact that the users chose not to independently digitize suggests that the new applications will have a lower average cost saving.

The average cost saving for current applications needs to be adjusted for all three of these factors.

Table 11 shows the impact of the agglomerative effect on the simple version of the estimated cost saving. See appendix D for a description of how the agglomerative effect is calculated. This effect reduces the value of lower levels of completion of the NDCDB.

Table 11. Agglomerative effect on cost saving (in millions of dollars)

	1994	1995	1996	1997	1998	1999	2000
Without initiative	9.2	14.9	20.7	26.3	31.4	36.7	41.5
With initiative	41.2	78.3	114.8	150.3	191.5	243.5	318.8

Net present value of cost savings = $681.2

Table 12 shows the impact of the priority effect on the simple version of the estimated cost saving. See appendix D for a description of how the priority effect is

calculated. This effect increases the value of lower levels of completion of the NDCDB.

Table 12. Priority effect on cost saving (in millions of dollars)

	1994	1995	1996	1997	1998	1999	2000
Without initiative	17.1	27.5	37.7	47.5	56.3	65.1	73.1
With initiative	72.6	128.8	175.8	213.6	243.6	272.7	285.8

Net present value of cost savings = $786.8

Table 13 shows the impact of diminishing returns on the simple version of the estimated cost saving. The size of the effect depends upon the speed with which diminishing returns to the use of GIS technology set in. The GIS community expects there will be significant and sustained growth in Federal GIS use over the rest of this decade. For example, the research firm Market Intelligence predicts a more than two-fold increase in Federal GIS expenditures between 1992 and 1997. This implies that diminishing returns are setting in very slowly (if at all) for Federal use of GIS technology. An estimate that the average cost saving from the new GIS applications are about two-thirds that from the current GIS applications is probably conservative. The values in table 13 are calculated by multiplying the simple version by two-thirds.

Table 13. -- Diminishing returns effect on cost saving (in millions of dollars)

	1994	1995	1996	1997	1998	1999	2000
Without initiative	6.8	11.0	15.2	19.3	23.1	26.9	30.5
With initiative	30.2	57.4	84.1	110.2	140.3	173.4	210.3

Net present value of cost savings = $481.3

Table 14 shows the combined impact of the agglomerative, priority, and diminishing returns effects. This is the best estimate of the cost saving generated by the new uses of GIS technology supported by the addition of DLG's to the NDCDB. See appendix E for a description of the calculation formula.

Table 14. Cost saving from new applications (best estimate version) (in millions of dollars)

	1994	1995	1996	1997	1998	1999	2000
Without initiative	10.9	17.5	24.1	30.0	35.9	41.5	46.5
With initiative	46.2	81.6	110.8	133.9	154.1	172.2	192.7

Net present value of cost savings = $501.3

8. Benefits of the Initiative

The benefits of the initiative are determined by comparing the total level of cost saving with the initiative to the total level of cost saving without the initiative. There are three components of the cost saving.

1. The base level of cost saving generated by the current Federal use of GIS technology. This is a total of about $450 million and was achieved when the NDCDB was 9.5 percent complete.

2. The elimination of duplicate digitizing (presently estimated as $18 million annually).

3. The cost saving generated by new uses of GIS technology. The new uses are made feasible by the availability of low-cost digital base cartographic data from the NDCDB.

Table 15 shows the cost saving by component for each of the 7 years of the initiative. The last row in the table shows the amount by which the cost saving with the initiative exceeds the cost saving without the initiative.

Table 15. Cost saving (in millions of dollars)

	1994	1995	1996	1997	1998	1999	2000
W/O initiative							
Base level	450.0	450.0	450.0	450.0	450.0	450.0	450.0
Dup. digit.	0.6	0.9	1.3	1.6	2.0	2.3	2.6
New applic.	10.9	17.5	24.1	30.3	35.9	41.5	46.5
Total	461.5	468.5	475.4	481.9	487.8	493.8	499.1
With initiative							
Base level	450.0	450.0	450.0	450.0	450.0	450.0	450.0
Dup. digit.	2.6	4.9	7.2	9.4	12.0	14.8	18.0
New applic.	46.2	81.6	110.8	133.9	154.1	172.2	192.7
Total	498.8	536.5	568.0	593.4	616.1	637.1	660.7
Increase	37.2	68.0	92.7	111.5	128.3	143.3	161.6

9. Comparison of Cost and Benefits

The benefits of the initiative are the increased cost saving each year. The cost of the initiative is the new expenditures on digitizing each year. Table 16 compares the cost and benefits of the initiative. The initiative generates positive net benefits every year after the first.

Table 16. Cost and benefits of the initiative (in millions of dollars)

	1994	1995	1996	1997	1998	1999	2000
Cost	40.3	39.4	38.6	37.8	45.1	50.4	57.2
Benefits	37.2	68.0	92.7	111.5	128.3	143.3	161.6
Net benefits	-3.1	28.6	54.1	73.7	83.2	92.9	104.4

Table 17 discounts the future cost and benefits at a rate of 7 percent per year, starting from the base year of 1993. Table 18 shows the net present values of the 7-year streams of costs and benefits and calculates a benefit to cost ratio of 2.3 to 1 for the initiative.

Table 17. Discounted cost and benefits (in millions of dollars)

	1994	1995	1996	1997	1998	1999	2000
Cost	37.7	34.4	31.5	28.8	32.2	33.6	35.6
Benefits	34.8	59.4	75.6	85.0	91.5	95.5	100.7
Net benefits	-2.9	25.0	44.1	56.2	59.3	61.9	65.0

Table 18. Net present value (in millions of dollars)

	Net present value
Cost	233.8
Benefits	542.5
Net benefits	308.7
Benefit to cost ratio	= 2.3 to 1

10. Effect of Lower Funding Levels

The preceding analysis assumes that the initiative is fully funded at a total of $308.8 million over a 7-year period. It would be possible to fund the initiative at a lower level. The effect of a lower level of funding would be to reduce the production rate of DLG's below what is necessary to complete the NDCDB by the end of fiscal year 2000. The benefits of having more DLG's in the NDCDB (elimination of duplicate digitizing and cost saving from new GIS applications) would still be attained, but the benefits would be smaller.

Table 19 shows the net present value of the initiative at a variety of lower funding levels. See appendix F for a discussion of how the values of lower funding levels were calculated.

Table 19. Net present value at lower funding levels (in millions of dollars)

Funding level	Discounted benefits	Discounted costs	Net present value
100%	542.5	233.8	308.7
90%	502.2	210.4	291.8
80%	460.7	187.0	273.7
70%	416.8	163.6	253.1
60%	369.9	140.3	229.6
50%	319.3	116.9	202.4
40%	264.2	93.5	170.7
30%	204.8	70.1	134.7
20%	141.1	46.8	94.3
10%	72.7	23.4	49.4

The initiative has a positive net present value even at the lowest funding level. The net present value of the initiative increases steadily as the funding level rises, with the largest net present value occurring when the initiative is fully funded.

11. Quality Assurance

a. Critical assumptions

The theoretical model used to estimate the benefits of the initiative is straightforward and not controversial. Briefly, the sole effect of the initiative is to accelerate the digitizing of base cartographic data from the USGS 1:24,000-scale primary map series. This means that, for each year of the initiative, the NDCDB will contain progressively more DLG's than it would in the absence of the initiative.

The addition of DLG's to the NDCDB has two major effects on GIS users. First, to the extent that the NDCDB contains the digital data that an agency needs, it eliminates the need for the agency to digitize these data independently. Second, it lowers the cost of obtaining digital base data, and so lowers the cost of using GIS technology. Some applications that were too expensive to do with GIS become cost effective because of the lower data cost.

The logic behind each of these effects is clear, and the direction of each of these effects is clear. Uncertainty arises with the attempt to estimate the magnitude of the effects. There are a number of critical assumptions that underlie the estimates made in this report.

Duplicate digitizing

The estimate of $18 million annually in duplicate digitizing is based on the following assumptions.

a. Current annual Federal expenditures on GIS technology are $900 million.

   This figure is quoted in the October 26, 1992, issue of "Government Computer News." It was developed by the research firm Market Intelligence following a series of interviews with leading Federal agencies. The $900 million figure is the Federal market for GIS "products." It almost certainly does not reflect large portions of the operating expenses incurred by Federal GIS installations. It is a conservative estimate of total current Federal GIS expenditures.

b. Average percent of total GIS costs due to digital data equals 75 percent.

   This is an accepted industry standard. The following quotes are typical:

   "75% of the budget will be devoted to database creation."
   (Aronoff, 1989, p. 9.)

"Current project experience suggests that initial data capture costs represent about 75% of the data management efforts."
(Bieber, 1988, p. 710.)

"It is a widely accepted fact that 70 to 90% of the cost of a GIS over its lifetime will be in the cost of building and maintaining the database."
(Walklet, 1991, p. 643.)

"As GIS practitioners know, map conversion is the most costly part of a GIS project, often consuming 75 percent of the budget."
(Cook, 1991, p. 108.)

"The typical user organization spends 65% to 75% of its GIS dollars on collecting and converting data."
(Daratech, Inc., 1989.)

"Some sources estimate the cost of a database to be as high as 75 percent of total system expenses."
(Antenucci, 1991, p. 58.

c. Base data themes compose 6 percent of all digital themes.

This is the reported experience of 13 Bureau of Indian Affairs offices that have used GIS since 1988. The major uncertainty is whether this experience is typical of all Federal GIS users. No study has been conducted that directly addresses this question. However, information collected in the Digital Benefits Study indicates that base themes compose less than 20 percent of all digital data used in Federal GIS applications. Because base data are multiuse themes, the actual percentage of base themes to all digital data is significantly lower than 20 percent.

d. Nonbase themes cost 2.25 times as much as base themes.

This is the reported cost ratio for 63 base and 67 nonbase data themes digitized by the Bureau of Indian Affairs in 1988. It is not known if this experience is typical for all Federal GIS users.

General assessment of the estimate of $18 million in duplicate digitizing: It is unlikely that duplicate digitizing expenses are lower than this. The USGS estimates it costs $7,500 to digitize the average 1:24,000-scale quadrangle. The estimate of $18 million implies the duplicate digitizing of about 2,400 quadrangles per year, which is less than 5 percent of the total number of quadrangles. Given the large unmet requirements for base digital data identified by the OMB Circular A-16 process, the single purpose digitization of under 5 percent of the

quadrangles per year appears to be a conservative estimate.

Number of new applications

The estimate of a 70-percent increase in the number of GIS applications is based on the following assumptions.

a. Percent of current applications using DLG's from the NDCDB equals 13.5 percent.

   This is the percent of applications using DLG's in a sample of 67 GIS applications studied in the Digital Benefits Study. The major uncertainly is whether the sample of 67 applications is representative of all Federal GIS applications.

b. Increase in applications using DLG's when DLG's are added to the NDCDB is in the proportion of 13.5 to 9.5.

   This assumption implies that applications are run at the quadrangle level, and that each quadrangle supports the same number of applications. This is not true. However, it is unclear how serious the deviations from the assumption are and how the deviations affect the number of new applications.

c. The NDCDB is currently 9.5 percent complete.

   The percentage of DLG's complete is 9.5. It is unclear if this is the appropriate way to measure the NDCDB. However, other potential ways of measuring the NDCDB yield a lower current level, which would lead to a higher estimate of new applications.

d. All current applications in the potential-use and likely-use categories will switch to NDCDB data when they are available.

   This is a reasonable assumption for the likely-use category. It is less reasonable for the potential-use category. Some potential-use applications would probably continue to use alternate sources of base data. The more potential-use applications that do not switch to DLG's, the larger is the number of new GIS applications supported by a complete NDCDB. For example, if none of the potential-use applications switched to the use of DLG's, the estimate of the number of new GIS applications would increase from 70.1 to 92.6 percentage points.

General assessment of the estimate of 70 percent additional GIS applications: This is an uncertain estimate. However, whatever the correct number might be, it is large. Evidence for this comes from an article on GIS in the October 26, 1992, issue of "Government Computer News." This article describes the rapid growth of the use of GIS technology in the Federal Government. For example, the Federal market for GIS purchases is expected to more than double in the next 5 years -- from $902 million in 1992 to an estimated $2.1 billion by 1997.

The article cites three major reasons for the rapid growth:

1. GIS hardware and software prices have dropped.
2. Reliable data bases and standards for data transfer are more readily available. Historically, one of the biggest obstacles to implementing a GIS, aside from price, was the limited availability of data.
3. Precise applications have emerged as prices dropped and data bases became available.

b. Sensitivity testing

The previous section describes some of the more important assumptions made in this study. How sensitive are the study's results to these assumptions? That is, does the finding that the initiative has large net benefits depend on the particular values used in the study?

What is the effect of changing the four major empirical assumptions used in the study?

1. The cost of duplicate digitizing. What is the impact if the cost is half the estimated level, or double the estimated level?

2. The cost saving from the current use of GIS technology. What is the impact if the current cost saving is half the estimated level, or double the estimated level?

3. The number of new GIS applications supported by a complete NDCDB. What is the impact if the number of new applications is half the estimated level, or double the estimated level?

4. The adjustments to the simple version of the estimated cost saving for the new applications. What is the impact if the priority and agglomerative effects are equal, or if the agglomerative effect dominates, or if the two effects are modeled differently? What is the impact if diminishing returns to the cost saving are much larger or much smaller than the estimated level?

The following five tables show the impact of changing each of the assumptions in turn, while holding all of the other study values constant. This isolates the impact of each assumption and permits the identification of the values that have the greatest influence on the finding of large net benefits for the initiative. The accuracy of the critical values directly affects the accuracy of the study findings.

Table 20 shows the impact of varying the estimate of duplicate digitizing by a factor of 4; between $9 million and $36 million.

Table 20. Alternate measures of duplicate digitizing

	1994	1995	1996	1997	1998	1999	2000
Without initiative							
$18 million	0.6	0.9	1.3	1.6	2.0	2.3	2.6
Half	0.3	0.5	0.7	0.8	1.0	1.1	1.3
Double	1.2	1.9	2.6	3.3	4.0	4.6	5.2
With initiative							
$12 million	2.6	4.9	7.2	9.4	12.0	14.8	18.0
Half	1.3	2.5	3.6	4.7	6.0	7.4	9.0
Double	5.2	9.8	14.4	18.9	24.0	29.7	36.0
Discounted benefits							
$18 million	34.8	59.4	75.6	85.0	91.5	95.5	100.7
Half	33.9	57.7	73.2	82.1	87.9	91.3	95.9
Double	36.7	62.9	80.5	91.0	98.6	103.8	110.2

Net present value		Benefit to cost ratio	
$18 million	308.7	$18 million	2.3
Half	288.1	Half	2.2
Double	349.9	Double	2.5

A change in the level of duplicate digitizing affects only the duplicate digitizing component of the benefits of the initiative. The study's results are not sensitive to the level of duplicate digitizing. A 400-percent increase in the estimate (from half to double) causes just over a 21-percent increase in the net present value of the initiative.

Table 21 shows the impact of varying the estimate of the current cost saving by a factor of 4; between $225 million and $900 million.

Table 21. Alternate measures of current cost saving (Benefit from new application)

	1994	1995	1996	1997	1998	1999	2000
Without initiative							
$450 million	10.9	17.5	24.1	30.3	35.9	41.5	46.5
$225 million	5.5	8.8	12.0	15.1	17.9	20.7	23.2
$900 million	21.9	35.1	48.1	60.5	71.7	82.9	93.0
With initiative							
$450 million	46.2	81.6	110.8	133.9	154.1	172.2	192.7
$225 million	23.1	40.8	55.4	67.0	77.0	86.1	96.4
$900 million	92.3	163.2	221.7	267.9	308.2	344.4	385.5
Discounted benefits							
$450 million	34.8	59.4	75.6	85.0	91.5	95.5	100.7
$225 million	18.3	31.4	40.2	45.5	49.3	51.9	55.1
$900 million	67.7	115.4	146.5	164.1	175.8	182.6	191.7

Net present value		Benefit to cost ratio	
$450 million	308.7	$450 million	2.3
$225 million	58.1	$225 million	1.2
$900 million	810.0	$900 million	4.5

A change in the current level of cost saving directly affects the base level and indirectly affects the cost saving of new applications by lowering the average cost saving of current applications. The study's results are quite sensitive to the level of the current cost saving. A 400-percent increase in the estimate (from half to double) causes nearly a 1,300-percent increase in the net present value of the initiative. However, the initiative remains cost effective even with the least favorable level of the current cost saving.

Table 22 shows the impact of varying the estimate of the number of new GIS applications by a factor of 4; between 35 percent and 140 percent.

Table 22. Alternate measures of number of new applications (Benefit from new applications)

	1994	1995	1996	1997	1998	1999	2000
Without initiative							
70 percent	10.9	17.5	24.1	30.3	35.9	41.5	46.5
Half	5.5	8.8	12.0	15.1	17.9	20.7	23.2
Double	21.9	35.1	48.1	60.5	71.7	82.9	93.0
With initiative							
70 percent	46.2	81.6	110.8	133.9	154.1	172.2	192.7
Half	23.1	40.8	55.4	67.0	77.0	86.1	96.4
Double	92.3	163.2	221.7	267.9	308.2	344.4	385.5
Discounted benefits							
70 percent	34.8	59.4	75.6	85.0	91.5	95.5	100.7
Half	18.3	31.4	40.2	45.5	49.3	51.9	55.1
Double	67.7	115.4	146.5	164.1	175.8	182.6	191.7

Net present value		Benefit to cost ratio	
70 percent	308.7	70 percent	2.3
Half	58.1	Half	1.2
Double	810.0	Double	4.5

A change in the number of new applications affects only the new applications component of the benefits of the initiative. The study's results are quite sensitive to the number of new applications. A 400-percent increase in the estimate (from half to double) causes nearly a 1,300-percent increase in the net present value of the initiative. However, the initiative remains cost effective even with the least favorable number of new applications.

Note: The results of changing the number of new applications are identical to the results of changing the level of the current cost saving. This is because the new applications component is calculated as (average cost saving x number of new applications). An equal percentage change in either factor has the same effect.

Table 23 shows the impact of varying the adjustment to the simple version of the estimated cost saving for new applications from a pure priority effect to a pure and very strong agglomerative effect.

Table 23. Alternate measures of adjusting simple version of the cost saving from new GIS applications (Benefit from new applications)

	1994	1995	1996	1997	1998	1999	2000
Without initiative							
Best estimate	10.9	17.5	24.1	30.3	35.9	41.5	46.5
Pure priority	10.5	16.8	23.1	29.0	34.4	39.8	44.7
Pure agglom.	1.0	1.8	2.8	3.9	5.1	6.4	7.8
With initiative							
Best estimate	46.2	81.6	110.8	133.9	154.1	172.2	192.7
Pure priority	48.4	85.9	117.2	142.4	165.0	181.8	190.5
Pure agglom.	7.7	21.9	42.6	69.1	107.8	159.8	230.1
Discounted benefits							
Best estimate	34.8	59.4	75.6	85.0	91.5	95.5	100.7
Pure priority	37.3	63.8	81.6	92.4	100.3	103.0	100.4
Pure agglom.	8.2	21.0	37.3	55.6	80.4	110.6	148.0

Net present value		Benefit to cost ratio	
Best estimate	308.7	Best estimate	2.3
Pure priority	345.1	Pure priority	2.5
Pure agglom.	227.3	Pure agglom.	2.0

A change in the adjustment factor for the average cost saving of new applications affects only the new applications component of the benefits of the initiative. The study's results are somewhat sensitive to the adjustment factor used. Ignoring the agglomerative effect causes about a 12-percent increase in the net present value. Using a very strong agglomerative effect and ignoring the priority effect causes more than a 26-percent decrease in the net present value. The various adjustment factors all result in roughly similar benefit to cost ratios. The main effect of changing the adjustment factors is in the timing of the benefits; the strong agglomerative effect greatly depresses the benefits in the earlier years of the initiative.

Table 24 shows the impact of applying the priority and agglomerative effects to the average value of new applications rather than to the total value (see appendix E for a discussion of the implications of this alternative approach).

Table 24. Alternate calculation formula for value of new applications (Benefit from new applications)

	1994	1995	1996	1997	1998	1999	2000
Without initiative							
Preferred formula	10.9	17.5	24.1	30.3	35.9	41.5	46.5
Alternate formula	9.4	15.1	20.7	26.1	30.8	35.7	40.0
With initiative							
Preferred formula	46.2	81.6	116.8	133.9	154.1	172.2	192.7
Alternate formula	39.7	69.9	94.4	113.4	129.4	143.8	161.0
Discounted benefits							
Preferred formula	34.8	59.4	75.6	85.0	91.5	95.5	100.7
Alternate formula	30.2	51.3	65.0	72.6	77.5	80.4	84.9

Net present value		Benefit to cost ratio	
Preferred formula	308.7	Preferred formula	2.3
Alternate formula	228.1	Alternate formula	2.0

A change in the formula used to calculate the cost saving of new applications affects only the new applications component of the benefits of the initiative. The study's results are somewhat sensitive to the formula used. Using the alternate formula causes about a 26-percent decrease in the net present value.

Table 25 shows the impact of varying the estimate of diminishing returns to the cost saving from zero effect to a 50-percent reduction.

Table 25. Alternate measures of diminishing returns to the cost saving (Benefit from new applications)

	1994	1995	1996	1997	1998	1999	2000
Without initiative							
Two-thirds	10.9	17.5	24.1	30.3	35.9	41.5	46.5
One-half	8.2	13.2	18.1	22.7	26.9	31.1	34.9
Zero	16.4	26.3	36.1	45.4	53.8	62.2	69.7
With initiative							
Two-thirds	46.2	81.6	116.8	133.9	154.1	172.2	192.7
One-half	34.6	61.2	83.1	100.5	115.6	129.2	144.6
Zero	69.3	122.4	166.2	200.9	231.1	258.3	289.1
Discounted benefits							
Two-thirds	34.8	59.4	75.6	85.0	91.5	95.5	100.7
One-half	26.6	42.3	54.1	60.8	65.2	67.8	72.2
Zero	51.3	87.4	111.1	124.6	133.6	139.0	146.2

Net present value		Benefit to cost ratio	
Two-thirds	308.7	Two-thirds	2.3
One-half	155.1	One-half	1.7
Zero	559.4	Zero	3.4

A change to the speed with which diminishing returns to cost saving set in affects only the new applications component of the benefits of the initiative. The study's results are fairly sensitive to the speed used. The net present value decreases by about 50 percent when the speed is raised and increases by 81 percent when the speed is slowed to zero.

General assessment of sensitivity testing:

1. The study results are insensitive to changes in the estimate of the amount of duplicate digitizing.

2. The study results are insensitive to most changes in the adjustments to the simple version of estimating the cost saving from new GIS applications. The major effect is to shift the time pattern of benefits rather than change the net present value of the initiative as a whole. However, strong emphasis on the

agglomerative factor or the use of an alternate calculation formula does cause a significant reduction in the net present value.

3. The study results are most sensitive to changes in the average value of new GIS applications. The value of the current cost saving, the number of new GIS applications, and the speed of diminishing returns to the cost saving are very different factors, but all impact the study results by affecting the average value of new GIS applications.

c. Conservative nature of estimates

The starting point for deriving the benefits of the initiative is the estimate that Federal use of GIS technology generates an annual cost saving of $450 million. Using $450 million as the base value leads to conservative results for four important reasons.

1. The estimate of $450 million measures GIS efficiency benefits only. Efficiency benefits are defined as the use of GIS technology to reduce the cost of producing the same products as were previously produced using manual methods.

   The estimate does not include any measure of effectiveness benefits. Effectiveness benefits arise when GIS technology is used to produce an product that either would not or could not be produced without the GIS. Preliminary results from the Digital Benefits Study indicate that effectiveness benefits are significantly larger than efficiency benefits.

   Excluding effectiveness benefits from the estimate significantly reduces the measured benefits of the initiative.

2. The estimate of $450 million measures only benefits to Federal agencies. It does not include benefits from GIS use by State or local governments or by the private sector. The aggregate level of GIS use by State and local governments is at least as great as that in the Federal sector.

   Excluding benefits for GIS users outside the Federal Government reduces the measured benefits of the initiative.

3. The estimate of $450 million measures the benefits of the current level of GIS use. No attempt is made to factor in future growth in the use of GIS technology. The estimates of new applications in the study measure the effect of adding DLG's to the NDCDB, holding constant the current level of investment in GIS

technology.

In fact, the level of investment in GIS technology in the Federal Government has been growing rapidly and is expected to continue to grow rapidly for the next several years. Additional investment in GIS technology increases the value of base cartographic data.

Excluding the growth effect of new Federal investment in GIS technology reduces the measured benefits of the initiative.

4. The estimate of $450 million measures the cost saving of the current level of GIS technology. No attempt is make to factor in future improvements in GIS software or hardware. Such improvements have been common in the past and are certain to continue. They can be expected to further lower the cost of running GIS applications.

   Excluding improvements in GIS technology reduces the measured benefits of the initiative.

In addition to the conservative nature of the estimate for the value of current GIS use, there are five other study features that lead to conservative results.

1. One effect of adding new DLG's to the NDCDB is that some current GIS users who use other types of base cartographic data would use DLG's from the NDCDB instead. The larger scale and higher quality of DLG's leads to improvements in these GIS applications. No attempt has been made to estimate the value of such improvements.

   Excluding this value reduces the measured benefits of the initiative.

2. The estimate of the cost of duplicate digitizing is based on the assumption that thematic to base data theme creation is in the ratio of 15 to 1. This is the measured ratio for established GIS installations. Beginning GIS installations require a larger proportion of base themes. The continuing extension of Federal GIS installations to new sites suggests that the $18 million estimate for the cost of duplicate digitizing is conservative.

   A higher estimate of the cost of duplicate digitizing would increase the measured benefits of the initiative.

3. The estimate of the number of new GIS applications supported by the addition of DLG's to the NDCDB is based on the assumption that all current potential-use applications will eventually switch to the use of DLG's from the NDCDB. This assumption leads to the smallest possible estimate of the number of applications that will switch from manual methods to the use of GIS technology as DLG's are added to the NDCDB.

   If, as is likely, some of the potential-use applications continue to use other types of base digital data, then the estimate of the number of new GIS applications is too low. For example, if only half of the potential-use applications switch to the use of DLG's, then the potential-use entry in table 8 at the 100-percent completion level would be 11.3 instead of 0; the "Shifted" entry would be 47.2 instead of 58.5, and the "New to GIS" entry would be 81.4 instead of 70.1. This is an 11.3 percentage-point increase in the number of new applications over the estimate used in this report.

   A conservative estimate of the number of new applications reduces the measured benefits of the initiative.

4. The estimate of the cost saving generated by the new GIS applications is based on the assumption of significant diminishing returns. The rapid historical growth of Federal GIS, and the expected continuation of such growth in the coming decade, suggests that diminishing returns are setting in very slowly, if at all.

   The assumption of significant diminishing returns reduces the measured benefits of the initiative.

5. The calculation of cost and benefits in this report stops in the year 2000. That is, benefits are calculated only during the 7-year duration of the initiative. In reality, completing the digitization of the primary map series by 2000 would continue to generate benefits for many years after that. The initiative would allow the capture of benefits to continue until approximately 2040; which is how long it would take to completely digitize the primary map series at the current production rate. Appendix G calculates the benefits for the first few years after the conclusion of the initiative. It shows, for example, that counting benefits through 2007 would increase the benefit to cost ratio from 2.3 to 4.8.

   The calculation of benefits is stopped in 2000 because the study's methodology of holding constant both GIS technology and Federal GIS investment becomes increasingly unrealistic, and thus its measurement of benefits increasingly unreliable, in these later years. Nevertheless, ignoring benefits that will be captured after its completion reduces the measured benefits of the initiative.

12. Economic Stimulus Effects

This cost-benefit analysis treats the initiative to accelerate the digitizing of 1:24,000-scale maps as though the initiative would exist in isolation from all other government programs. This is done to bring the direct effects of the initiative clearly into focus. In reality, the initiative would interact with a variety of existing government initiatives and programs and, thereby, produce indirect effects as well.

The clearest interactions would be with the existing USGS programs of Mapping Partnerships and the Department of the Interior (DOI) Digitizing Contract. The Digitizing Contract provides a mechanism by which DOI bureaus can coordinate their individual digitizing efforts. This will work to ensure that the elimination of duplicate digitizing assumed in the analysis actually takes place.

USGS Mapping Partnerships extend beyond the DOI to other Federal, State, and local government agencies; public utilities; and the private sector. The USGS uses Cooperative Program resources to fund up to 50 percent of the cost of an individual mapping partnership project. Federal and non-Federal partners can pool their resources with the USGS to generate digital products at significant cost reductions. This program not only helps to eliminate duplicate digitizing, but also works to ensure that the DLG's actually prepared serve highly valued uses. Recent joint funding and data exchange agreements with the City of Austin, Electric Utility; Lake County, Illinois; and the State of Idaho demonstrate the successful use of mapping partnerships.

Constrained resources make it important to establish partnerships and share resources that build spatial data bases that are multipurpose in nature. The extra funding provided by the initiative will not produce new DLG's in isolation, but will operate through existing programs. It will channel new projects to the digitizing industry, create new jobs, and stimulate growth and investment in GIS technology.

High-quality, low-cost digital base cartographic data are critical to the continued growth of GIS technology. GIS technology epitomizes the President's call for "Technology for America's Economic Growth." The continued spread of GIS technology will mean more high-skill, high-wage jobs for American workers. It will help the private sector remain competitive and maintain U.S. leadership in critical world markets. It gives the scientific and technological research community a powerful tool for focusing on the quality of life - promoting long term economic growth that both creates jobs and protects the environment.

These economic stimulus effects of the initiative are real, but have not been included in the cost-benefit analysis. The benefits cited in this study are the direct benefits of the initiative only.

13. Conclusion

There are large net benefits to be gained by funding the initiative to accelerate the digitizing of 7.5-minute maps. Even a low level of additional funds for digitizing yields positive net benefits. As the level of funding increases, so too do the net benefits, with the greatest net benefits achieved when the initiative is fully funded.

Accelerating the completion of the NDCDB generates a significant cost saving. The saving comes from two sources:

1. elimination of duplicate digitizing, and
2. the cost saving from new GIS applications supported by the increased availability of low-cost base digital data from the NDCDB.

The cost saving from new GIS applications is many times higher than the saving from eliminating duplicate digitizing. Duplicate digitizing is a multimillion dollar problem, but it is trivial compared to the cost to Federal agencies of delaying the application of GIS technology.

Tasks well suited to GIS technology are presently being handled by more expensive manual techniques simply because the initial cost of independently digitizing base data themes is prohibitive. Every day that the NDCDB remains woefully incomplete means a multitude of lost opportunities for a cost saving. The elimination of duplicate digitizing is a desirable side effect, but the overriding reason for accelerating the completion of the NDCDB is to promote the use of cost effective GIS techniques. The potential saving from the expansion of GIS use dwarfs even the worst estimates of the inefficiencies of duplicate digitizing.

The specific values cited in this report cannot be considered anything more than a first approximation of the actual benefits of the initiative. Some of the values used to derive the estimates are preliminary and are likely to change given further research. However, the finding of positive net benefits for the initiative does not depend on the specific values used in this report. The initiative yields positive net benefits under a wide range of possible values. Even under the least favorable assumptions tested the initiative still has a benefit to cost ratio of 1.2 to 1.

The finding of positive net benefits is reinforced by the conservative nature of many aspects of the study. Consideration of benefits other than cost reductions, of benefits to users outside the Federal Government, and of expected future growth in GIS use, all point to significant further increases in the value of the initiative.

In addition to the benefits cited in the report, the initiative would complement and support existing programs such as the USGS Mapping Partnerships and the DOI Digitizing Contract by channeling new projects to the digitizing industry, creating new jobs, and stimulating growth and investment in GIS technology.

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APPENDIXES

APPENDIX A

CURRENT EFFICIENCY BENEFITS OF GIS USE

It is estimated that Federal agencies currently reduce costs by $450 million annually by using GIS technology. This estimate is a preliminary finding of the Digital Benefits Study. Following is a brief description of this study and how the $450 million estimate was made.

1. Brief description of the Digital Benefits Study

The purpose of the Digital Benefits Study is to determine the value of having primary map data in digital form. Primary map data are the types of data included on a USGS topographic map; for example, elevation data, hydrography data, transportation data, and political boundaries.

The value of digital cartographic data is measured by the value of the use of that data. Digital data are not final products, but are used as input to the production process. They are valuable only to the extent that someone puts them into a computer and does things with them. Putting digital cartographic data into a computer and doing something with them is a simple definition of a GIS. The value of digital data is closely connected with the value of GIS technology.

The approach is to develop a general model of the benefits of having spatial data in digital form and then to narrow the focus to primary map data in digital form. This involves four steps.

Step 1 - Determine how to measure the value of GIS use for a specific application.

Step 2 - Generalize the results of step 1 into a model that will predict the benefits of GIS use for an application.

Step 3 - Use the model from step 2 to estimate the benefits of GIS use across all Federal applications.

Step 4 - Identify what portion of the benefits estimated in step 3 are attributable to primary map data in digital form.

There are two qualitatively different types of benefits obtained from GIS technology; efficiency benefits and effectiveness benefits. Efficiency benefits are when the GIS is used to do the same task as was previously done without a GIS. The same quality of output is produced, but at a lower cost. Effectiveness benefits are when the GIS is

used to improve the quality of a current product, or to create a product not previously available. The GIS is used to do something that either could not or would not be done without it.

Techniques to measure both types of benefits were developed in cooperation with more than 40 Federal GIS users in more than 60 studies of successful GIS applications. The key to measuring benefits is to identify what has changed because of the GIS. For efficiency benefits what has changed is the resources needed to create the product. This is measured as the reduction in variable costs for running the application. For effectiveness benefits what has changed is the product of the application. The value of this depends on the effect the changed product has on each user.

The digital benefits tests provide a data base of nearly 70 separate measurements of GIS benefits. There is a great deal of variation in the size of benefits from one application to the next. A large amount of the variation can be explained by a small number of objective and easy to measure characteristics of the applications.

The digital benefits model consists of two equations: one to predict efficiency benefits and one to predict effectiveness benefits. The efficiency equation is based on 30 separate measurements of benefits and explains 73 percent of the observed variation in efficiency benefits. The effectiveness equation is based on 38 separate measurements and explains 77 percent of the observed variation in effectiveness benefits. Both equations are statistically significant at the 99-percent confidence level.

2. How the $450 million estimate was made

The digital benefits model will predict efficiency and effectiveness benefits for any GIS application for which the values of the independent variables are known. To directly estimate the benefits of GIS use across the entire Federal Government would require collection of the values of the independent variable for all applications -- a monumental task. Instead, Federal GIS applications are divided into a number of smaller subsets. The subsets group together applications with similar values for the independent variables.

The average values within each subset represent the "typical" values of the independent variables for that subset. When these typical values are put into the digital benefits equations, the output is a prediction of the average efficiency and effectiveness benefits for all applications in the subset.

Using the typical values of the independent variables means that it is not necessary to collect these values for all Federal applications. All that is needed is the number of

applications that fall into each subset. This information was collected from a sample of Federal GIS users and extrapolated to the Federal Government.

The efficiency equation does not predict efficiency benefits directly, but rather predicts the ratio of efficiency benefits to manual cost. That is, the equation predicts the percentage of the manual cost saved by the use of GIS technology. To convert the ratio into dollar benefits, it must be multiplied by the manual cost of the application. Information on average manual cost was also collected from sample Federal GIS users.

Efficiency benefits for each Federal agency are estimated by multiplying the number of applications in each subset with efficiency benefits times the average manual cost times the predicted ratio of efficiency benefits to manual cost for that subset. The predicted efficiency benefits for the Federal Government is the sum of the benefits for each individual agency. The preliminary estimate of this is $450 million.

Quality assurance work is continuing on the Digital Benefits Study. It is likely that the $450 million estimate of efficiency benefits will be modified during the quality checking. However, it is unlikely that the final estimate will be dramatically different from the preliminary estimate. This is partly because the total manual cost provides an upper limit to the efficiency estimate and partly because the quality checking done to date has resulted in only small changes to the aggregate efficiency benefits estimate.

A particularly important aspect of the quality checking is the question of how well the case study applications in the digital benefits tests represent all Federal GIS applications. This question is examined in appendix H.

3. What the $450 million estimate means (and doesn't mean)

The prediction of $450 million is an estimate of the annual GIS efficiency benefits to the Federal Government. That is, it is an estimate of how much less it costs to run the applications using GIS technology than it costs to run the applications using another method. It is an estimate of the reduction in operating expenses gained by the use of GIS technology.

The estimate concerns variable cost (the cost incurred in the actual running of an application). The estimate does not address fixed cost (the cost that must be incurred before an application can be run for the first time). For example, before any GIS application can be run it is necessary to obtain GIS hardware and software, trained staff to run the equipment, and a data base of digital data. This is the fixed cost of establishing a GIS capability.

Efficiency benefits show that when a GIS capability has been established, there are applications that can be run less expensively using GIS methods than using the previous manual methods. Efficiency benefits do not guarantee that it will be cost effective to make the initial investment to establish a GIS capability. Efficiency benefits measure the potential gains from establishing a GIS capability. To decide if the initial establishment of a GIS capability is a good investment, it is necessary to compare these potential gains against the cost of establishing a GIS capability. For example, it wouldn't make much sense to spend $1,000,000 in a fixed cost to get the opportunity to save $100,000 in a variable cost.

The $450 million estimate measures the gains from the use of a GIS. It does not compare those gains with the fixed cost of the investment that made the gains possible.

The difference between a fixed and a variable cost does not, however, have any effect on finding a large benefit to cost ratio for the initiative to accelerate the digitization of primary map information. The method used in this study holds the level of investment in GIS technology constant. Both the "with initiative" and "without initiative" scenarios include the same amount of GIS hardware and software and support staff. The level of fixed cost is the same whether or not the initiative is carried out. The initiative changes the variable cost, not the fixed cost. The expenditures made to establish the current level of GIS capability are a sunk cost. Only changes in the variable cost are relevant for assessing the benefits of the initiative.

Note: The method of holding constant the level of investment in GIS technology assumes that there is sufficient excess capacity in existing GIS hardware installations to support the new GIS applications. Interviews conducted with all major Federal GIS users suggest that this is not an unreasonable assumption.

APPENDIX B

FUTURE PRODUCTION OF DLG'S

The current percent of DLG's in the NDCDB is known - 48,080 completed DLG's divided by 504,000 total DLG's equals 9.5 percent complete. The future percent of DLG's in the NDCDB depends on the rate of production of new DLG's. The following describes the information used and assumptions made to predict the future production rate of DLG's.

1. Without the initiative

Table 26 shows how many DLG's of each category will be produced each year through fiscal year 2000 in the absence of the initiative. That is, it shows the results of current and planned levels of expenditures on digitization, absent any new funds from the initiative.

Table 26. Production rate without initiative

	Number of DLG's completed during fiscal year							
Category	1993	1994	1995	1996	1997	1998	1999	2000
PLSS	800	750	750	750	750	750	700	650
Boundary	935	950	950	970	920	880	800	750
Hydro.	1,060	1,000	1,020	1,030	950	900	850	800
Trans.	745	1,000	1,020	1,030	950	900	850	800
MMF	390	1,060	1,070	1,090	1,040	975	1,000	960
Control	355	1,060	1,070	1,090	1,040	975	1,000	960
Veg.	355	1,060	1,070	1,090	1,040	975	1,000	960
Nonveg.	355	1,060	1,070	1,090	1,040	975	1,000	960
Hypso.	465	1,060	1,070	1,090	1,040	975	1,000	960
Total	5,460	9,000	9,090	9,230	8,770	8,305	8,200	7,800

This information was provided by the USGS's Office of Production Management. The projections are based on the current cost of digitizing each data category and are adjusted for

a. An expected increase in funds available for digitizing in fiscal year 1994. This increase is outside and independent of the initiative.

b. Expected increases in efficiencies in contracting for digitizing services through fiscal year 1996.

c. An expected reduction in real value of budgeted funds because of inflation.

Table 27 shows the cumulative number of DLG's of each category that will be complete each year through fiscal year 2000. The percents shown in table 2 (see p. 5) are calculated by dividing each of the cumulative numbers by the total number of DLG's.

Table 27. Number of DLG's complete without the initiative

	Number of DLG's in the NDCDB by end of fiscal year							
Category	1993	1994	1995	1996	1997	1998	1999	2000
PLSS	14,139	14,889	15,639	16,389	17,139	17,889	18,589	19,239
Boundary	17,096	18,046	18,996	19,966	20,886	21,766	22,566	23,316
Hydro.	6,992	7,992	9,012	10,042	10,992	11,892	12,742	13,542
Trans.	6,661	7,661	8,681	9,711	10,661	11,561	12,411	13,211
MMF	1,567	2,627	3,697	4,787	5,827	6,802	7,802	8,762
Control	1,590	2,650	3,720	4,810	5,850	6,825	7,825	8,785
Veg.	1,595	2,655	3,725	4,815	5,855	6,830	7,830	8,790
Nonveg.	1,580	2,640	3,710	4,800	5,840	6,815	7,815	8,775
Hypso.	2,320	3,380	4,450	5,540	6,580	7,555	8,555	9,515
Total	53,540	62,540	71,630	80,860	89,630	97,935	106,135	113,935

2. With the initiative

The initiative provides for the digitization of all DLG's by fiscal year 2000. Table 28 shows the total number of DLG's of each category whose digitization will be funded by the initiative.

Table 28. DLG's funded by the initiative

		DLG's complete in FY 2000 without the initiative		DLG's funded by the initiative	
Category	Total DLG's	Number	Percent	Number	Percent
PLSS	40,000	19,239	48.1	20,761	51.9
Boundary	58,000	23,316	40.2	34,684	59.8
Hydro.	58,000	13,542	23.3	44,458	76.7
Trans.	58,000	13,211	22.8	44,789	77.2
MMF	58,000	8,762	15.1	49,238	84.9
Control	58,000	8,785	15.1	49,215	84.9
Veg.	58,000	8,790	15.2	49,210	84.8
Nonveg.	58,000	8,775	15.1	49,225	84.9
Hypso.	58,000	9,515	16.4	48,485	83.6
Total	504,000	113,935	22.6	390,065	77.4

The proportion of the 390,065 additional DLG's completed each year over the 7-year duration of the initiative depends on the funding profile of the initiative. Total DLG production each year is proportional to the expenditures each year. Table 29 shows this relationship. The funding profile for the initiative comes from the latest version of the initiative, dated December 14, 1992.

Table 29. DLG production by year

Fiscal Year	New funds from initiative	% of total new funds	Number of DLG's completed
1994	40.3	13.05	50,906
1995	39.4	12.76	49,769
1996	38.6	12.50	48,758
1997	37.8	12.24	47,748
1998	45.1	14.60	56,969
1999	50.4	16.32	63,663
2000	57.2	18.53	72,253
Total	308.8	100.0	390,065

There are numerous ways in which the digitization of the additional DLG's each year could be spread over the nine DLG categories. To project production rates by DLG category by year, it is necessary to make two assumptions.

1. It is assumed that an equal proportion of all DLG categories will be digitized during a year. This means that the USGS will not concentrate on digitizing one particular DLG category first, but will digitize all nine DLG categories at about the same rate. This assumption matches the strategy the USGS reports they would follow in the absence of the initiative.

2. It is assumed that the new funds provided by the initiative are used to digitize DLG's over and above what would be done without the initiative. That is, the projected DLG production in each category shown in table 25 would still be done; the initiative would provide for digitizing additional DLG's in each category.

Table 30 shows the expected DLG production by category for the 7 years of the initiative. Table 31 shows the cumulative number of DLG's of each category that will be complete each year through fiscal year 2000. The percents shown in table 3 are calculated by dividing each of the cumulative numbers by the total number of DLG's.

Table 30. DLG production with the initiative

	Number of DLG's completed in fiscal year						
Category	1994	1995	1996	1997	1998	1999	2000
PLSS	3,459	3,399	3,345	3,291	3,781	4,088	4,497
Boundary	5,476	5,376	5,306	5,165	5,944	6,460	7,177
Hydro.	6,802	6,693	6,587	6,392	7,391	8,106	9,038
Trans.	6,845	6,735	6,629	6,432	7,439	8,160	9,099
MMF	7,486	7,353	7,245	7,067	8,164	9,036	10,084
Control	7,483	7,350	7,242	7,064	8,160	9,032	10,080
Veg.	7,482	7,349	7,241	7,063	8,160	9,031	10,079
Nonveg.	7,484	7,351	7,243	7,065	8,162	9,034	10,081
Hypso.	7,387	7,257	7,151	6,975	8,054	8,913	9,944
Total	59,903	58,862	57,988	56,514	65,254	71,859	80,079

Table 31. Number of DLG's complete with the initiative

	Number of DLG's in the NDCDB by end of fiscal year						
Cateogry	1994	1995	1996	1997	1998	1999	2000
PLSS	17,598	20,997	24,343	27,634	31,415	35,503	40,000
Boundary	22,572	27,948	33,253	38,419	44,363	50,823	58,000
Hydro.	13,794	20,487	27,074	33,466	40,856	48,962	58,000
Trans.	13,506	20,241	26,870	33,302	40,741	48,901	58,000
MMF	9,053	16,405	23,650	30,717	38,881	47,916	58,000
Control	9,073	16,422	23,664	30,728	38,889	47,920	58,000
Veg.	9,077	16,426	23,667	30,731	38,890	47,921	58,000
Nonveg.	9,064	16,415	23,658	30,723	38,885	47,919	58,000
Hypso.	9,707	16,964	24,115	31,089	39,143	48,056	58,000
Total	113,443	172,305	230,293	286,807	352,062	423,920	504,000

APPENDIX C

OTHER WAYS TO MEASURE THE STATUS OF THE NDCDB

Percent of DLG's digitized is not the only way to measure the status of the NDCDB. Two alternative measures look at what percent of the total work effort has been accomplished and what percent of the total volume of digital data has been digitized. These are not the same as the percent of DLG's digitized, because some categories of DLG's are more difficult to digitize and involve a larger volume of digital data.

Table 32 shows the weights assigned to each category. The geodetic control data category requires the least work effort and involves a small volume of digital data. The other categories are expressed as multiples of the geodetic control data category. Table 33 shows the three different measures of the status of the NDCDB in 2000 in the absence of the initiative.

Table 32. Weight of the DLG categories

Category	Work effort	Volume of data
PLSS	3.5	4.0
Boundary	2.2	0.5
Hydro.	8.0	16.8
Trans.	7.7	22.2
MMF	10.9	9.5
Control	1.0	1.0
Veg.	4.2	22.1
Nonveg.	1.1	1.0
Hypso.	16.0	75.4

Table 33. Comparison of other ways to measure status of NDCDB

	Status of NDCDB	
Measure	In FY 1992	In FY 2000
Number of DLG's	9.5	22.6
Work Effort	7.3	20.4
Volume of Data	5.4	18.5

The number of DLG's measure has the largest values. This is because fewer DLG's of the larger and more difficult categories have been digitized to date. Using either of the alternative measures in place of the number of DLG's measure would lead to significantly higher estimated benefits for the initiative. The number of DLG's measure is preferred because it is simple and is a conservative approach.

APPENDIX D

CALCULATION OF AGGLOMERATIVE AND PRIORITY EFFECTS

1. Agglomerative effect

The agglomerative effect says that the last DLG's produced are more valuable than the first DLG's produced. This is because some applications require complete coverage of large areas and having incomplete DLG coverage is of limited value.

The agglomerative effect is modeled by the following relative percentages:

1 to 70 percent	=	0.9
71 to 80 percent	=	1.0
81 to 90 percent	=	1.2
91 to 100 percent	=	1.5

Table 34 shows the individual and cumulative agglomerative effect.

2. Priority effect

The priority effect says that the first DLG's produced are more valuable than the last DLG's produced. That is, some DLG's are more valuable than others, and USGS managers concentrate on producing the more valuable DLG's first.

The priority effect is modeled by the rule of 78. This rule assigns a relative value of 100 to the first percent of DLG's produced, a value of 99 to the second percent, a value of 98 to the third, and so on. This model has the feature that each percent of DLG's produced is only slightly more valuable than the next percent, but that the earlier DLG's are much more valuable than the later DLG's. The portion of total value accounted for by each percent of DLG's is calculated as the relative value of that percent of DLG's divided by the total relative value (5,050) for all DLG's.

For example, the portion of total value accounted for by the first percent of DLG's produced is:

$$100 \div 5050 = 1.98\%$$

Table 35 shows the individual and cumulative priority effect.

Table 34. Agglomerative effect

Pct.	Value of pct.	Cumulative value	Pct.	Value of pct.	Cumulative value	Pct.	Value of pct.	Cumulative value
1	0.9	0.9	35	0.9	31.5	68	0.9	61.2
2	0.9	1.8	36	0.9	32.4	69	0.9	62.1
3	0.9	2.7	37	0.9	33.3	70	0.9	63.0
4	0.9	3.6	38	0.9	34.2	71	1.0	64.0
5	0.9	4.5	39	0.9	35.1	72	1.0	65.0
6	0.9	5.4	40	0.9	36.0	73	1.0	66.0
7	0.9	6.3	41	0.9	36.9	74	1.0	67.0
8	0.9	7.2	42	0.9	37.8	75	1.0	68.0
9	0.9	8.1	43	0.9	38.7	76	1.0	69.0
10	0.9	9.0	44	0.9	39.6	77	1.0	70.0
11	0.9	9.9	45	0.9	40.5	78	1.0	71.0
12	0.9	10.8	46	0.9	41.4	79	1.0	72.0
13	0.9	11.7	47	0.9	42.3	80	1.0	73.0
14	0.9	12.6	48	0.9	43.2	81	1.2	74.2
15	0.9	13.5	49	0.9	44.1	82	1.2	75.4
16	0.9	14.4	50	0.9	45.0	83	1.2	76.6
17	0.9	15.3	51	0.9	45.9	84	1.2	77.8
18	0.9	16.2	52	0.9	46.8	85	1.2	79.0
19	0.9	17.1	53	0.9	47.7	86	1.2	80.2
20	0.9	18.0	54	0.9	48.6	87	1.2	81.4
21	0.9	18.9	55	0.9	49.5	88	1.2	82.6
22	0.9	19.8	56	0.9	50.4	89	1.2	83.8
23	0.9	20.7	57	0.9	51.3	90	1.2	85.0
24	0.9	21.6	58	0.9	52.2	91	1.5	86.5
25	0.9	22.5	59	0.9	53.1	92	1.5	88.0
26	0.9	23.4	60	0.9	54.0	93	1.5	89.5
27	0.9	24.3	61	0.9	54.9	94	1.5	91.0
28	0.9	25.2	62	0.9	55.8	95	1.5	92.5
29	0.9	26.1	63	0.9	56.7	96	1.5	94.0
30	0.9	27.0	64	0.9	57.6	97	1.5	95.5
31	0.9	27.9	65	0.9	58.5	98	1.5	97.0
32	0.9	28.8	66	0.9	59.4	99	1.5	98.5
33	0.9	29.7	67	0.9	60.3	100	1.5	100.0
34	0.9	30.6						

Table 35. Priority effect

Pct.	Value of pct.	Cumulative value	Pct.	Value of pct.	Cumulative value	Pct.	Value of pct.	Cumulative value
1	1.98	1.98	35	1.31	57.52	68	0.65	89.54
2	1.96	3.94	36	1.29	58.81	69	0.63	90.18
3	1.94	5.88	37	1.27	60.08	70	0.61	90.79
4	1.92	7.80	38	1.25	61.33	71	0.59	91.39
5	1.90	9.70	39	1.23	62.55	72	0.57	91.96
6	1.88	11.58	40	1.21	63.76	73	0.55	92.51
7	1.86	13.45	41	1.19	64.95	74	0.53	93.05
8	1.84	15.29	42	1.17	66.12	75	0.51	93.56
9	1.82	17.11	43	1.15	67.27	76	0.50	94.06
10	1.80	18.91	44	1.13	68.40	77	0.48	94.53
11	1.78	20.69	45	1.11	69.50	78	0.46	94.99
12	1.76	22.46	46	1.09	70.59	79	0.44	95.43
13	1.74	24.20	47	1.07	71.66	80	0.42	95.84
14	1.72	25.92	48	1.05	72.71	81	0.40	96.24
15	1.70	27.62	49	1.03	73.74	82	0.38	96.61
16	1.68	29.31	50	1.01	74.75	83	0.36	96.97
17	1.66	30.97	51	0.99	75.74	84	0.34	97.31
18	1.64	32.61	52	0.97	76.71	85	0.32	97.62
19	1.62	34.24	53	0.95	77.66	86	0.30	97.92
20	1.60	35.84	54	0.93	78.59	87	0.28	98.20
21	1.58	37.43	55	0.91	79.50	88	0.26	98.46
22	1.56	38.99	56	0.89	80.40	89	0.24	98.69
23	1.54	40.53	57	0.87	81.27	90	0.22	98.91
24	1.52	42.06	58	0.85	82.12	91	0.20	99.11
25	1.50	43.56	59	0.83	82.95	92	0.18	99.29
26	1.49	45.05	60	0.81	83.76	93	0.16	99.45
27	1.47	46.51	61	0.79	84.55	94	0.14	99.58
28	1.45	47.96	62	0.77	85.33	95	0.12	99.70
29	1.43	49.39	63	0.75	86.08	96	0.10	99.80
30	1.41	50.79	64	0.73	86.81	97	0.08	99.88
31	1.39	52.18	65	0.71	87.52	98	0.06	99.94
32	1.37	53.54	66	0.69	88.22	99	0.04	99.98
33	1.35	54.89	67	0.67	88.89	100	0.02	100.00
34	1.33	56.22						

APPENDIX E

FORMULA FOR THE COST SAVING FROM NEW APPLICATIONS

The addition of more DLG's to the NDCDB supports some applications that would not use GIS technology without the availability of low-cost base digital data. The use of GIS technology reduces the cost of these applications over what it would cost using manual methods. The cost saving generated by the new GIS applications is calculated according to the following formula:

Percent of new applications x the average cost saving of current applications x agglomerative plus priority effects x diminishing returns effect

where the average cost saving of current applications = $4.50 million
diminishing returns effect = two-thirds
agglomerative plus priority effects =
(cumulative agglomerative value + cumulative priority value
- percent completion of NDCDB) ÷ percent completion of NDCDB
x value adjustment at 9.5 percent complete
value adjustment = value remaining ÷ DLG's remaining
= 82.94 ÷ 90.5 = 0.916

Example #1:

In 1994, when the NDCDB would be 22.5 percent complete under the initiative (see table 3).
Percent of new applications = 10.08 (table 9)
Cumulative agglomerative value = 20.25 (table 34)
Cumulative priority value = 39.76 (table 35)

Cost saving = 10.08 x $4.50M x ((39.76+20.25-22.5) ÷ 22.5 x 0.916) x 2/3

= $45.36M x 1.527 x 2/3

= $46.2 million

Example #2:

In 1996, when the NDCDB would be 45.7 percent complete under the initiative (see table 3).

Percent of new applications = 28.04 (table 9)
Cumulative agglomerative value = 41.13 (table 34)
Cumulative priority value = 70.26 (table 35)

Cost saving = 28.04 x \$4.50M x ((70.26+41.13-45.7) ÷ 45.7 x 0.916) x 2/3

= \$126.18M x 1.317 x 2/3

= \$110.8 million

The formula for the cost saving from new applications basically says that the total value of the new applications supported by a complete NDCDB is two-thirds of the level predicted by the simple version. The lowering of the total value from the simple version is the diminishing returns effect. The priority and agglomerative effects mostly affect the timing of the benefits rather than the total value. The priority effect causes earlier DLG's to be more valuable. The agglomerative effect causes later DLG's to be more valuable.

This is not the only possible way to calculate the cost saving from new applications. An alternate approach is to apply the priority and agglomerative effects to the average value of the applications rather than to the total value. Using this approach the priority effect acts to reduce the average value of applications as more DLG's are digitized, while the agglomerative effect acts to increase the average value of applications.

Figures 2 and 3 show the trends in the total cost saving under the preferred and alternate calculation formulas and the influence of each factor. Using the preferred formula the priority and agglomerative effects primarily affect the timing of benefits, not the amount. This is shown in figure 2 by the clustering of the values for a complete NDCDB around the simple version total. The alternate formula allows the priority and agglomerative effects to affect the amount of benefits. This is shown in figure 3 by the much wider dispersion of the values for a complete NDCDB.

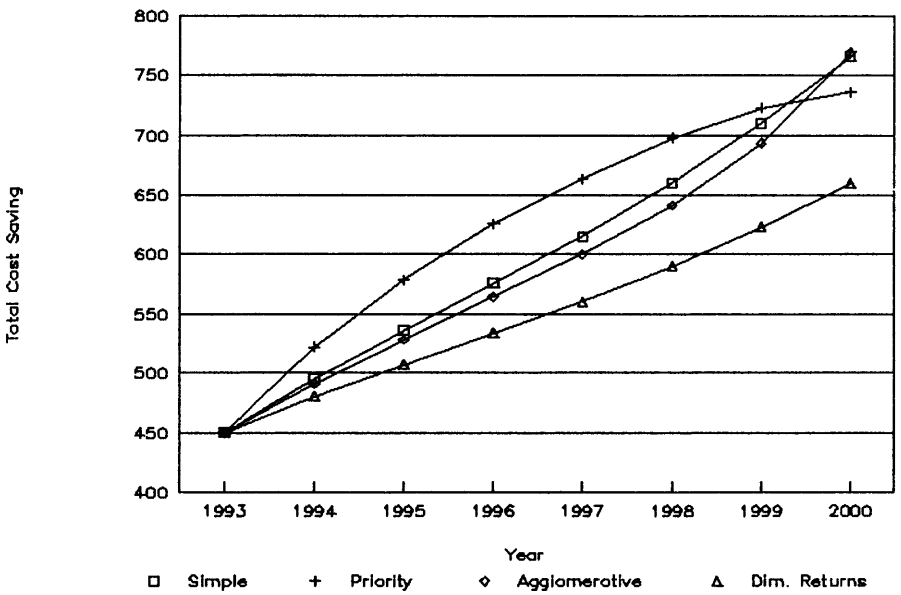

Figure 2. Total cost saving using preferred formula.

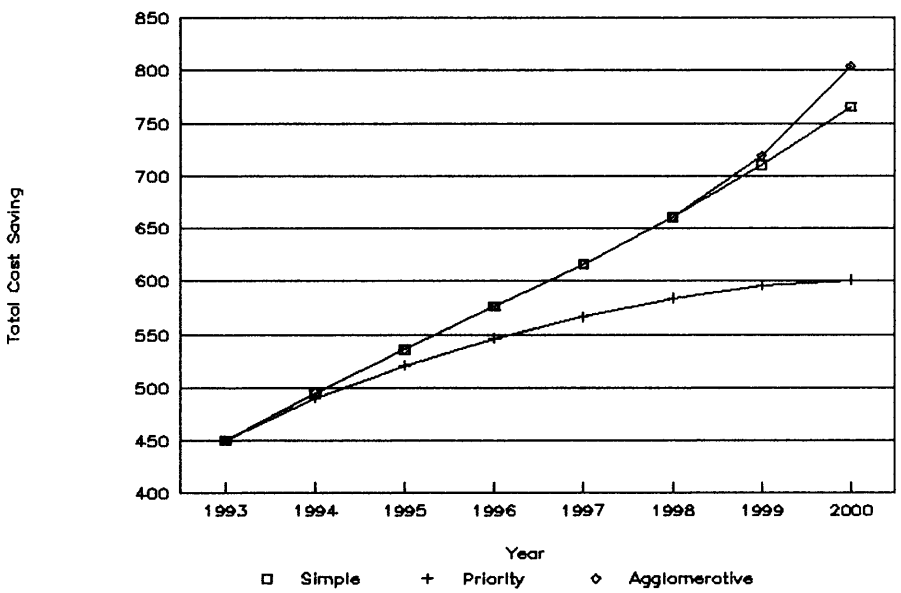

Figure 3. Total cost saving using alternate formula.

Figures 4 and 5 show the trends in the average value of one percentage point of applications under the preferred and alternate calculation formulas. Using the preferred formula the priority effect causes the average value first to rise and then to fall. Using

the alternate formula the priority effect causes the average value to continuously fall.

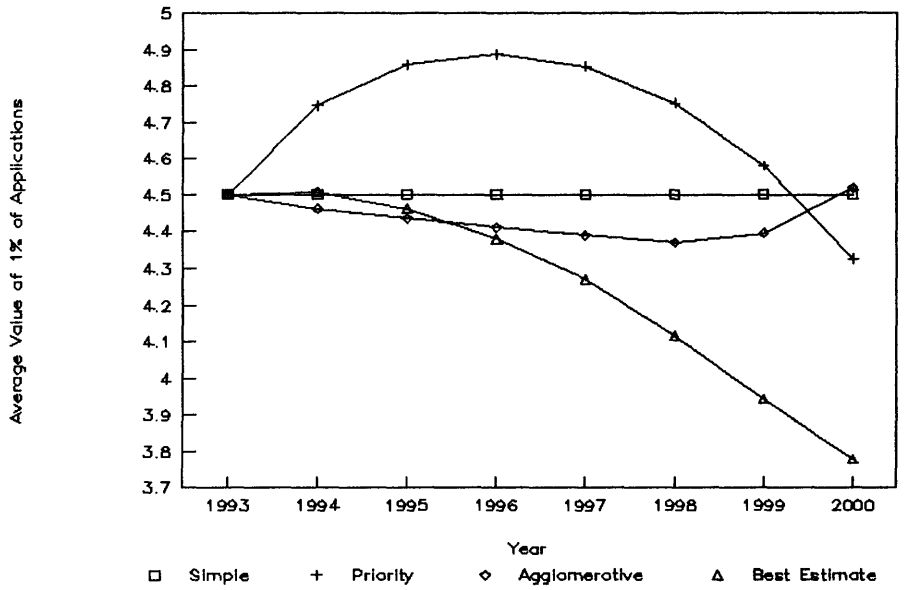

Figure 4. Average value of applications using preferred formula.

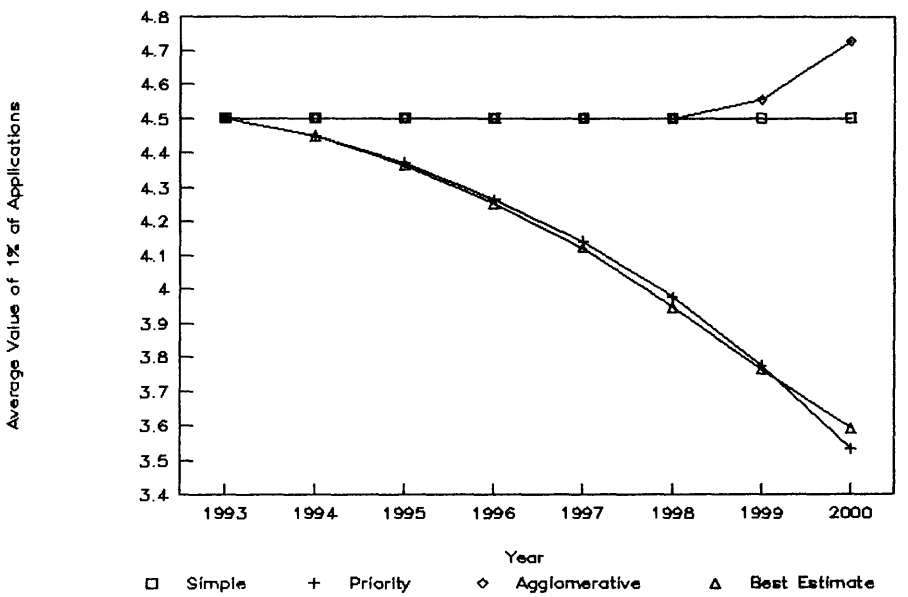

Figure 5. Average value of applications using alternate formula.

The preferred and alternate calculation formulas incorporate the priority and agglomerative effects in quite different ways. However, the best estimate predictions of

the total cost saving are similar no matter which formula is used. Figure 6 compares the trends in the average values under the two different approaches.

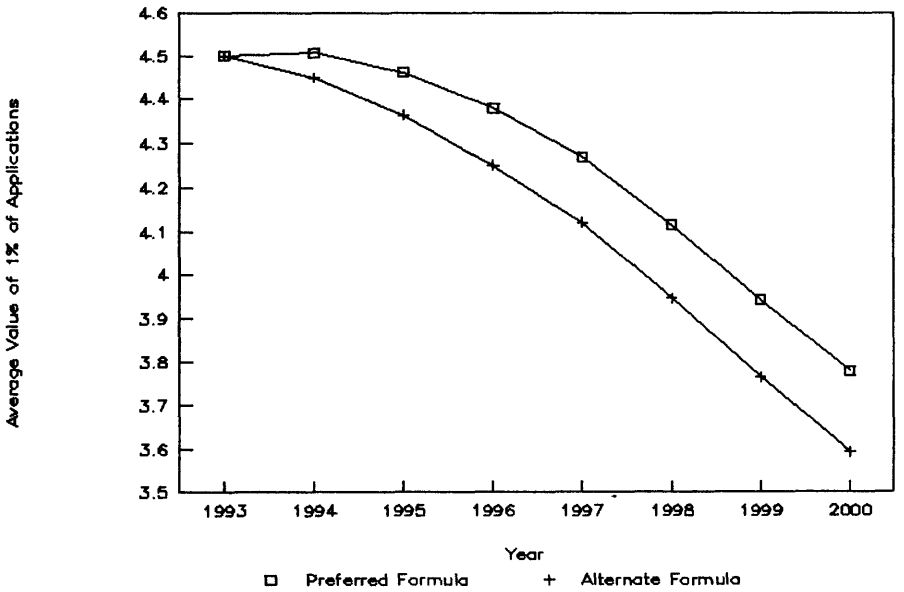

Figure 6. Comparison of calculation formulas.

The trend has the same basic shape under either formula. The alternate formula consistently predicts slightly lower average values than does the preferred formula. Average values using the alternate formula range from 99 percent of the preferred formula value in 1994 to 95 percent in 2000.

APPENDIX F

VALUE OF THE INITIATIVE AT LOWER FUNDING LEVELS

Lower levels of funding for the initiative would mean that fewer DLG's could be completed each year. It is assumed that there is a one-to-one relationship between funding and DLG production. That is, a 10-percent reduction in funding causes a 10-percent reduction in the number of DLG's produced.

Tables 36 through 46 show the effect of various lower levels of funding for the initiative.

- Table 36 shows the effect on the production rate of DLG's.
- Table 37 shows the effect on the number of DLG's complete.
- Table 38 shows the effect on the percent of DLG's complete.
- Table 39 shows the effect on the reduction of duplicate digitizing.
- Table 40 shows the effect on the cost saving from new applications.
- Tables 41 through 43 show the effect on the benefits, cost, and net benefits of the initiative.
- Tables 44 through 46 show the effect on the discounted benefits, cost, and net benefits of the initiative.

Table 36. Production rate of DLG's at lower funding levels

	1994	1995	1996	1997	1998	1999	2000
W/0 initiative	9,000	9,090	9,230	8,770	8,305	8,200	7,800
With initiative							
10% funding	14,090	14,067	14,106	13,544	14,000	14,566	15,028
20% funding	19,181	19,044	18,982	18,319	19,685	20,932	22,256
30% funding	24,271	24,022	23,857	23,093	25,390	27,298	29,484
40% funding	29,361	28,999	28,733	27,868	31,085	33,664	36,712
50% funding	34,452	33,976	33,609	32,642	36,780	40,030	43,940
60% funding	39,542	38,953	38,485	37,416	42,474	46,395	51,167
70% funding	44,632	43,930	43,361	42,191	48,169	52,761	58,395
80% funding	49,722	48,908	48,236	46,965	53,864	59,127	65,623
90% funding	54,813	53,885	53,112	51,740	59,559	65,493	72,851
100% funding	59,903	58,862	57,988	56,514	65,254	71,859	80,079

Table 37. Number of DLG's complete at lower funding levels

	1994	1995	1996	1997	1998	1999	2000
W/0 initiative	62,540	71,630	80,860	89,630	97,935	106,135	113,935
With initiative							
10% funding	67,630	81,698	95,803	109,348	123,348	137,914	152,941
20% funding	72,721	91,765	110,747	129,065	148,760	169,692	191,948
30% funding	77,811	101,833	125,690	148,783	174,173	201,471	230,954
40% funding	82,901	111,900	140,633	168,501	199,585	233,249	269,961
50% funding	87,992	121,968	155,577	188,219	224,998	265,028	308,967
60% funding	93,082	132,035	170,520	207,936	250,411	296,806	347,973
70% funding	98,172	142,103	185,463	227,654	275,823	328,585	386,980
80% funding	103,262	152,170	200,406	247,372	301,236	360,363	425,986
90% funding	108,353	162,238	215,350	267,089	326,648	392,142	464,993
100% funding	113,443	172,305	230,293	286,807	352,061	423,920	503,999

Table 38. Percent of DLG's complete at lower funding levels

	1994	1995	1996	1997	1998	1999	2000
W/0 initiative	12.4	14.2	16.0	17.8	19.4	21.1	22.6
With initiative							
10% funding	13.4	16.2	19.0	21.7	24.5	27.4	30.3
20% funding	14.4	18.2	22.0	25.6	29.5	33.7	38.1
30% funding	15.4	20.2	24.9	29.5	34.6	40.0	45.8
40% funding	16.4	22.2	27.9	33.4	39.6	46.3	53.6
50% funding	17.5	24.2	30.9	37.3	44.6	52.6	61.3
60% funding	18.5	26.2	33.8	41.3	49.7	58.9	69.0
70% funding	19.5	28.2	36.8	45.2	54.7	65.2	76.8
80% funding	20.5	30.2	39.8	49.1	59.8	71.5	84.5
90% funding	21.5	32.2	42.7	53.0	64.8	77.8	92.3
100% funding	22.5	34.2	45.7	56.9	69.9	84.1	100.0

Table 39. Reduction of duplicate digitizing at lower funding levels (in millions of dollars)

	1994	1995	1996	1997	1998	1999	2000
W/0 initiative	0.6	0.9	1.3	1.6	2.0	2.3	2.6
With initiative							
10% funding	0.8	1.3	1.9	2.4	3.0	3.6	4.1
20% funding	1.0	1.7	2.5	3.2	4.0	4.8	5.7
30% funding	1.2	2.1	3.1	4.0	5.0	6.1	7.2
40% funding	1.4	2.5	3.7	4.8	6.0	7.3	8.8
50% funding	1.6	2.9	4.3	5.5	7.0	8.6	10.3
60% funding	1.8	3.3	4.8	6.3	8.0	9.8	11.8
70% funding	2.0	3.7	5.4	7.1	9.0	11.1	13.4
80% funding	2.2	4.1	6.0	7.9	10.0	12.3	14.9
90% funding	2.4	4.5	6.6	8.7	11.0	13.6	16.5
100% funding	2.6	4.9	7.2	9.4	12.0	14.8	18.0

Table 40. Cost saving from new applications at lower funding levels (in millions of dollars)

	1994	1995	1996	1997	1998	1999	2000
W/0 initiative	10.9	17.5	24.1	30.3	35.9	41.5	46.5
With initiative							
10% funding	14.6	24.7	34.5	43.5	52.6	61.7	70.5
20% funding	18.3	31.7	44.5	56.1	68.1	80.2	92.1
30% funding	21.9	38.5	54.0	68.1	82.7	97.0	111.1
40% funding	25.5	45.2	63.2	79.4	96.0	112.2	127.7
50% funding	29.2	51.7	72.2	90.1	108.3	125.7	141.6
60% funding	32.7	58.0	80.5	100.3	119.7	137.5	153.0
70% funding	36.1	6461	88.7	109.7	129.8	147.6	163.2
80% funding	39.5	70.1	96.5	118.4	139.0	156.4	172.7
90% funding	42.9	76.0	103.8	126.5	147.0	164.3	182.4
100% funding	46.2	81.6	110.8	133.9	154.1	172.2	192.7

Table 41. Benefits of the initiative at lower funding levels (in millions of dollars)

Funding level	1994	1995	1996	1997	1998	1999	2000
10% funding	3.9	7.5	10.9	14.0	17.8	21.4	25.5
20% funding	7.8	14.9	21.6	27.4	34.3	41.2	48.7
30% funding	11.6	22.2	31.6	40.2	49.9	59.3	69.2
40% funding	15.4	29.2	41.5	52.3	64.2	75.7	87.3
50% funding	19.3	36.1	51.0	63.7	77.5	90.5	102.8
60% funding	22.9	42.8	60.0	74.7	89.9	103.5	115.7
70% funding	26.6	49.4	68.7	84.9	101.0	114.9	127.5
80% funding	30.2	55.8	77.1	94.4	111.2	124.9	138.5
90% funding	33.7	62.0	85.0	103.2	120.3	134.1	149.8
100% funding	37.3	68.0	92.6	111.5	128.3	143.3	161.6

Table 42. Cost of the initiative at lower funding levels (in millions of dollars)

Funding level	1994	1995	1996	1997	1998	1999	2000
10% funding	4.0	3.9	3.9	3.8	4.5	5.0	5.7
20% funding	8.1	7.9	7.7	7.6	9.0	10.1	11.4
30% funding	12.1	11.8	11.6	11.3	13.5	15.1	17.2
40% funding	16.1	15.8	15.4	15.1	18.0	20.2	22.9
50% funding	20.2	19.7	19.3	18.9	22.6	25.2	28.6
60% funding	24.2	23.6	23.2	22.7	27.1	30.2	34.3
70% funding	28.2	27.6	27.0	26.5	31.6	35.3	40.0
80% funding	32.2	31.5	30.9	30.2	36.1	40.3	45.8
90% funding	36.3	35.5	34.7	34.0	40.6	45.4	51.5
100% funding	40.3	39.4	38.6	37.8	45.1	50.4	57.2

Table 43. Net benefits of the initiative at lower funding levels (in millions of dollars)

Funding level	1994	1995	1996	1997	1998	1999	2000
10% funding	-0.1	3.6	7.1	10.3	13.3	16.4	19.8
20% funding	-0.3	7.0	13.8	19.9	25.2	31.1	37.3
30% funding	-0.5	10.3	20.0	28.8	36.3	44.2	52.0
40% funding	-0.7	13.4	26.1	37.1	46.2	55.5	64.4
50% funding	-0.9	16.4	31.7	44.8	54.9	65.3	74.2
60% funding	-1.2	19.2	36.8	52.0	62.8	73.3	81.4
70% funding	-1.6	21.8	41.7	58.4	69.5	79.6	87.4
80% funding	-2.1	24.2	46.3	64.1	75.2	84.6	92.8
90% funding	-2.5	26.5	50.2	69.2	79.7	88.8	98.3
100% funding	-3.0	28.6	54.0	73.7	83.2	92.9	104.4

Table 44. Discounted benefits of the initiative at lower funding levels (in millions of dollars)

Funding level	1994	1995	1996	1997	1998	1999	2000
10% funding	3.7	6.6	8.9	10.7	12.7	14.3	15.9
20% funding	7.3	13.0	17.6	20.9	24.4	27.5	30.3
30% funding	10.8	19.3	25.8	30.6	35.6	39.5	43.1
40% funding	14.4	25.5	33.9	39.9	45.8	50.4	54.4
50% funding	18.0	31.5	41.6	48.6	55.3	60.3	64.0
60% funding	21.4	37.4	49.0	57.0	64.1	69.0	72.1
70% funding	24.8	43.1	56.1	64.7	72.0	76.6	79.4
80% funding	28.2	48.7	63.0	72.0	79.3	83.2	86.3
90% funding	31.5	54.1	69.4	78.8	85.7	89.4	93.3
100% funding	34.8	59.4	75.6	85.0	91.5	95.5	100.7

Table 45. Discounted cost of the initiative at lower funding levels (in millions of dollars)

Funding level	1994	1995	1996	1997	1998	1999	2000
10% funding	3.8	3.4	3.2	2.9	3.2	3.4	3.6
20% funding	7.5	6.9	6.3	5.8	6.4	6.7	7.1
30% funding	11.3	10.3	9.5	8.7	9.6	10.1	10.7
40% funding	15.1	13.8	12.6	11.5	12.9	13.4	14.2
50% funding	18.8	17.2	15.8	14.4	16.1	16.8	17.8
60% funding	22.6	20.6	18.9	17.3	19.3	20.2	21.4
70% funding	26.4	24.1	22.1	20.1	22.5	23.5	24.9
80% funding	30.1	27.5	25.2	23.1	25.7	26.9	28.5
90% funding	33.9	31.0	28.4	26.0	28.9	30.2	32.1
100% funding	37.7	34.4	31.5	28.8	32.2	33.6	35.6

Table 46. Discounted net benefits of the initiative at lower funding levels (in millions of dollars)

Funding level	1994	1995	1996	1997	1998	1999	2000
10% funding	-0.1	3.1	5.8	7.8	9.5	10.9	12.3
20% funding	-0.3	6.2	11.3	15.2	18.0	20.7	23.2
30% funding	-0.5	9.0	16.4	22.0	25.9	29.4	32.4
40% funding	-0.7	11.7	21.3	28.3	32.9	37.0	40.1
50% funding	-0.8	14.3	25.9	34.2	39.2	43.5	46.2
60% funding	-1.2	16.7	30.0	39.7	44.8	48.8	50.7
70% funding	-1.5	19.0	34.1	44.6	49.5	53.1	54.4
80% funding	-1.9	21.2	37.8	48.9	53.6	56.4	57.8
90% funding	-2.4	23.2	41.0	52.8	56.8	59.2	61.2
100% funding	-2.8	25.0	44.1	56.2	59.3	61.9	65.0

APPENDIX G

BENEFITS BEYOND 2000

The initiative will complete digitization of the primary map series in 2000. The size of the benefits of the initiative in later years depends on what percent of the DLG's would be digitized without the initiative. Benefits will continue to accrue until such time as the NDCDB is complete (approximately 2040 at current production rates).

The benefits come from the same source as the benefits measured for 1994 through 2000:

1. reduction in duplicate digitizing, and
2. the cost saving from new GIS applications.

The size of these benefits declines in later years as, even without the initiative, an ever larger number of DLG's are added to the NDCDB. Tables 47 through 53 calculate the benefits of the initiative for an additional 7 years (for 2001 through 2007).

The current planned production rate is about 9,000 DLG's per year. It costs about $7.5 million per year to produce 9,000 DLG's. It is assumed that this production rate will continue.

Table 47. Percent of DLG's in NDCDB (2001-2007)

	2001	2002	2003	2004	2005	2006	2007
Without initiative	24.4	26.2	28.0	29.8	31.6	33.4	35.2
With initiative	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 48. Amount of duplicate digitizing eliminated (2001-2007) (in millions of dollars)

	2001	2002	2003	2004	2005	2006	2007
Without initiative	3.0	3.3	3.7	4.0	4.4	4.8	5.1
With initiative	18.0	18.0	18.0	18.0	18.0	18.0	18.0

Table 49. New GIS applications (2001-2007)

	2001	2002	2003	2004	2005	2006	2007
Without initiative	11.5	12.9	14.3	15.7	17.1	18.5	19.9
With initiative	70.1	70.1	70.1	70.1	70.1	70.1	70.1

Table 50. Cost saving from new applications (2001-2007) (in millions of dollars)

	2001	2002	2003	2004	2005	2006	2007
Without initiative	11.5	12.9	14.3	15.7	17.1	18.5	19.9
With initiative	192.7	192.7	192.7	192.7	192.7	192.7	192.7

Table 51. Total cost saving (2001-2007) (in millions of dollars)

	2001	2002	2003	2004	2005	2006	2007
Without initiative							
Base level	450.0	450.0	450.0	450.0	450.0	450.0	450.0
Duplicate digit.	3.0	3.3	3.7	4.0	4.4	4.8	5.1
New applications	52.3	58.0	63.5	69.0	74.2	79.4	84.4
Total	505.3	511.3	517.2	523.0	528.6	534.1	539.5
With initiative							
Base level	450.0	450.0	450.0	450.0	450.0	450.0	450.0
Duplicate digit.	18.0	18.0	18.0	18.0	18.0	18.0	18.0
New applications	192.7	192.7	192.7	192.7	192.7	192.7	192.7
Total	660.7	660.7	660.7	660.7	660.7	660.7	660.7
Increase	155.5	149.4	143.5	137.7	132.1	126.6	121.3

Up to 2000, the cost of the initiative is the additional expenditure on digitizing over and above the expenditure for the normal planned production level. After 2000, not only will there be no additional expenditure under the initiative, but there will be no need to spend even for the planned production level, since the NDCDB will be complete. This means that the cost of the initiative (the difference between spending under the initiative and spending for the planned production level) is actually negative after 2000.

Table 52. Cost and benefits of the initiative (2001-2007) (in millions of dollars)

	2001	2002	2003	2004	2005	2006	2007
Cost	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5
Benefits	155.5	149.4	143.5	137.7	132.1	126.6	121.3
Net Benefits	163.0	156.9	151.0	145.2	139.6	134.1	128.8

Table 53. Discounted cost and benefits (2001-2007) (in millions of dollars)

	2001	2002	2003	2004	2005	2006	2007
Costs	-4.4	-4.1	-3.8	-3.6	-3.3	-3.1	-2.9
Benefits	90.5	81.3	73.0	65.4	58.7	52.5	49.9
Net Benefits	94.9	85.4	76.8	69.0	62.0	55.7	49.9

Table 54 shows how the addition of benefits after the year 2000 affects the net present value and benefit to cost ratio of the initiative.

Table 54. Net present value (1994-2007)

	1994-2000	1994-2007
Net present value		
Cost	233.8	208.6
Benefits	542.5	1,010.9
Net benefits	308.7	802.3
Benefit to cost ratio	2.3	4.8

APPENDIX H

ARE THE GIS CASE STUDIES REPRESENTATIVE?

The Digital Benefits Study rests on a foundation of more than 60 case studies of successful Federal GIS applications. The benefits measured in these studies were used to estimate the coefficients of the digital benefits model. The independent variables measured were used to develop the typical values for the application subsets. The incidence of use of NMD primary map data (both digital and graphic) identified in these studies was used to estimate the number of new GIS applications supported by the addition of DLG's to the NDCDB. Given the empirical significance of the studies, it is important to assess the degree to which they are representative of all Federal GIS applications.

The case studies are the result of a two-stage sampling process. The first stage was the selection of organizations using GIS technology. The second stage was the selection of specific applications within each organization. Neither stage involved a random sample.

First stage of sample selection

The organization stage involved a universe sample. All 30 agencies interviewed by the USGS for the Primary Mapping Economic Analysis Phase One were selected. Table 55 lists these 30 Federal agencies and the result of each interview.

The sample is a good representation of Federal GIS users. It closely matches the findings of the 1988 Federal Geographic Data Committee (FGDC) Federal GIS Users Survey. Most of the case study agencies reported to the FGDC that they had operational use of GIS technology. Of the 27 agencies listed by the FGDC survey as having operational use of GIS technology, 24 are in the case study sample.

The sample also matches the findings of the 1990 FGDC Federal GIS Users Survey. All but four of the case study agencies reported to the FGDC that they had operational use of GIS technolgy. Of the eight agencies listed by the FGDC survey as having the most extensive use of GIS, all are in the case study sample.

There was an 80-percent cooperation rate; 24 of the 30 sample units were successfully interviewed. Of the four agencies that did not have any appropriate GIS applications, three had been reported in the FGDC surveys as not having operational GIS use. The only real concern is that the Defense Mapping Agency and the Central Intelligence Agency did not cooperate in the test; these are both agencies the FGDC reports as being among the most extensive GIS users. However, their absence is a nonresponse error, not a sampling error.

Table 55. Agencies contacted for digital benefits case studies

Agency	Interview status
Department of the Interior	
Bureau of Indian Affairs	Successful (3 offices)
Bureau of Land Management	Successful
Bureau of Mines	No appropriate applications
Bureau of Reclamation	Successful (4 offices)
Fish and Wildlife Service	Successful
Geological Survey	Successful (4 offices)
Minerals Management Service	Successful
National Park Service	Successful
Office of Surface Mining	Successful
Federal Geographic Data Committee (FGDC)	
Defense Mapping Agency	Unable to participate
Department of Energy	Successful (2 offices)
Environmental Protection Agency	Successful
Federal Emergency Management Agency	Partly successful
Federal Highway Administration	Successful
Forest Service	Successful
National Aeronautics and Space Administration	No appropriate applications
National Ocean Service	Successful (2 offices)
Agencies outside DOI and FGDC	
Agency for International Development	Successful
Bureau of Labor Statistics	Successful
Bureau of the Census	Successful
Central Intelligence Agency	Unable to participate
Customs Service	No appropriate applications
Federal Communications Commission	Successful
National Agricultural Statistics Service	Successful (2 offices)
National Environmental Satellite, Data, and Information Service	Successful (2 offices)
National Marine Fisheries Service	No appropriate applications
Soil Conservation Service	Successful (3 offices)
Tennessee Valley Authority	Successful
U.S. Army Corps of Engineers	Successful (3 offices)
Naval Oceanographic and Atmospheric Research Laboratory	Successful

Second stage of sample selection

The application stage involved a guided self-selection by the respondents. Respondents were asked to suggest one or more successful GIS applications. "Successful" was not defined as an application having large benefits. Rather, it was subjectively defined as an application where the GIS worked well; a task on which the agency would use the GIS again. To what extent did this guided self-selection yield a representative sample of GIS applications? Are there large numbers of unsuccessful GIS applications that were systematically excluded from the selection process? Both logic and empirical results suggest that the application sample is broadly representative and that there are not large numbers of unsuccessful applications dragging down the average GIS benefit estimates.

Consider first the definition of successful as being a task on which the GIS would be used again. No one would suggest that every GIS application is successful, but an "unsuccessful" application is less likely to be repeated. Applications that have been put into regular operational use are most likely to be successful. Unsuccessful applications are more likely to be tried once or twice and then discontinued. This is especially true for applications with efficiency benefits. These are applications whose primary purpose is to lower the cost of performing some task that would be done manually in the absence of the GIS. Repeated occurrences of an unsuccessful efficiency application would require an agency to deliberately continue to spend more than is necessary to accomplish a task that used to be done less expensively, claiming that this is being done to save money. Perverse behavior such as this may occur occasionally, but is unlikely to be widespread.

The case studies provide empirical support for this common sense conclusion. The case study applications are run nearly 5,500 times per year, for an average frequency of occurrence of more than 80 per year. Anecdotal evidence from several respondents concern instances where a GIS was tried on a task, was found not to work very well, and so was not done again. Successful applications are run frequently; unsuccessful applications are not.

The case study applications cover a broad range of uses. The USGS has developed a classification scheme for the uses of geographic information that groups applications according to their primary function. Table 56 shows the distribution of the case study applications across the 16 categories in the USGS classification scheme.

There is a wide dispersion across the categories. Fifteen of the sixteen primary functions are represented, and no primary function accounts for as much as 20 percent of the total number of applications. This suggests that the case study applications are representative of the diverse uses of a GIS.

Table 56. Classification by primary function

Primary function	Number of applications
Agriculture	3
Commerce and economic development	4
Defense, law enforcement, and emergency preparedness	2
Energy and mineral management	4
Environmental protection	2
Fish and wildlife management	6
Forestry	10
Geological surveys	2
Land management	5
Library and academic research	3
Parks and recreation	7
Soils	1
Taxation and revenue	0
Transportation	1
Urban and regional planning	2
Water resources	10

Additional evidence supporting the representativeness of the case study applications comes from later interviews with a sample of 23 Federal GIS users. Respondents at these agencies reported their total number of GIS applications and classified them by general type. The great majority of the reported applications are the same general type as the case study applications. Table 57 compares the two different sets of applications data. All quantities are shown as percentages to facilitate comparisons. The 24 categories classify efficiency applications according to 4 factors:

1. Complexity of application: small, moderately complex, or big.

2. Source of complexity (applies to moderately complex applications only): sheer size, complex analysis, many uses, or no one factor dominates.

3. Broad type of application: land or nonland.

4. Cost of running application manually: low or high.

Table 57. Comparison of case studies to all GIS applications

Category	Case studies	All appl.
Small		
Land		
Low	10.3	21.0
High	0.0	0.0
Nonland		
Low	17.2	27.8
High	0.0	0.2
Moderate/Size		
Land		
Low	10.3	7.9
High	13.8	0.2
Nonland		
Low	3.4	1.4
High	3.4	0.5
Moderate/Analysis		
Land		
Low	0.0	3.2
High	0.0	0.0
Nonland		
Low	0.0	0.9
High	6.9	0.1

Category	Case studies	All appl.
Moderate/Uses		
Land		
Low	10.3	8.4
High	3.4	0.0
Nonland		
Low	6.9	6.9
High	0.0	0.0
Moderate/No one factor		
Land		
Low	0.0	13.3
High	3.4	0.3
Nonland		
Low	10.3	1.9
High	0.0	0.2
Big		
Land		
Low	0.0	3.5
High	0.0	0.4
Nonland		
Low	0.0	1.1
High	0.0	0.3

For the case studies, 16 of the 24 categories contain less than 5 percent of the applications. Only 1 of these 16 categories contains more than 5 percent of the larger set of applications.

For the case studies, eight of the categories contain more than 5 percent of the applications. Five of these eight categories also contain more than 5 percent of the larger set of applications.

The six most common case study categories contain 72 percent of the applications. The same six categories contain 67 percent of the larger set of applications.

The match between the two sets of applications data is not perfect, but it is remarkably close considering the radically different sampling methods used to obtain them. The case study applications appear to be broadly representative of the total set of applications for the sampled agencies. There is no evidence of any widespread systematic discrepancy.

*U.S. G.P.O.:1993-301-077:80042