Final Report
NOAA BPA EA133C17BA0058
TO - C0001- Scoping the Value of the Regional Geodetic Advisor Program

revised

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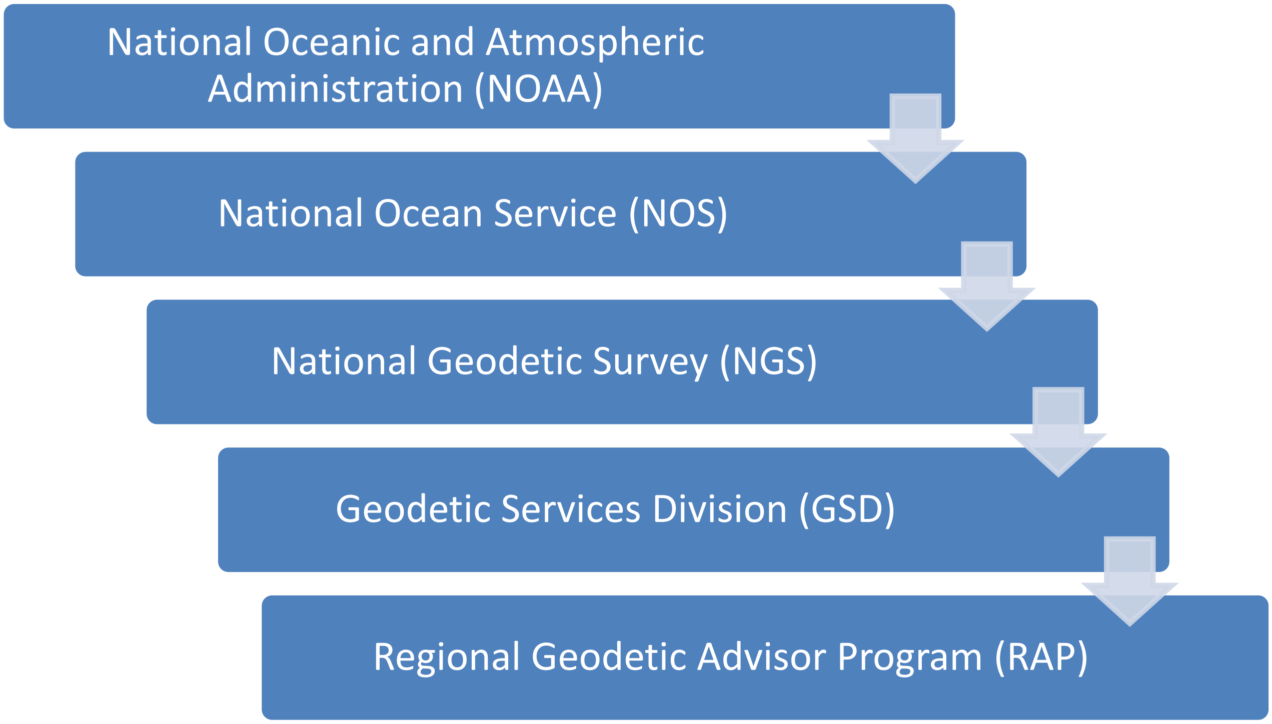
National Oceanic and Atmospheric Administration (NOAA)
National Ocean Service (NOS)
National Geodetic Survey (NGS)
Geodetic Services Division (GSD)
Regional Geodetic Advisor Program (RAP)

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Preface

The National Geodetic Survey (NGS) provides the foundation of the National Spatial Reference System (NSRS), making use of geodesy to develop and maintain reference standards and tools to utilize them. The National Academy of Sciences report on precise geodetic infrastructure defines the domain of geodesy as:

> "The fundamental parameters of geodesy include the Earth's shape (land and sea surface topography, bathymetry, and ice sheet thickness), rotation and orientation in space, and gravity field. These parameters all change with time as a consequence of the dynamic nature of the Earth's system. Geophysical processes transform the Earth's surface, modifying the distribution of mass within the Earth's interior and its oceans, and consequently alter its gravity field and rotation."[1]

NGS provides access to its data, tools and training through extensive outreach efforts via documents, conferences and online capabilities as well as email and telephone support. The Regional Geodetic Advisor Program provides technical assistance and personal and group training to users of the National Spatial Reference System (NSRS) in their home regions to facilitate proper use of modern positioning technologies, NGS geodetic data and tools, and federal positioning standards. The program began in mid-2016 as a successor to the State Geodetic Advisor Program.

The objective of this socio-economic scoping study is to preliminarily assess the nature and benefits of the Regional Geodetic Advisor Program. Benefit information can be useful in improving understanding of customers, applications and requirements for program planning, informing decisions about the allocation of resources among programs, and for advancing recognition of the contributions of the program.

This effort has benefited from exceptional cooperation and assistance from NGS staff in providing information and from the insights of NGS staff and people interviewed. We wish to thank Brett Howe and Ross Mackay for their guidance and perceptions, Joe Evjen, Rick Foote, Christine Gallagher, Julian Inasi, Erika Little, Brian Shaw, Mark Schenewerk, and Steve Vogel for providing data and contributing to discussions, Juliana Blackwell, Jessica Doten, Maureen Green, Brad Kearse and Sherri Watkins for their participation in meetings, and Mark Cheves, Dan Martin, Scott Martin, David Newcomer, William Stone and David Zilkoski for information and contributions to our understanding. Special thanks to Ross Mackay and William Stone for detailed comments on drafts of the report.

Responsibility for the content lies with Irv Leveson, the technical lead, who conducted the main analyses and prepared the report.

[1] National Academy of Sciences, *Precise Geodetic Infrastructure: National Requirements for a Shared Resource*, National Academies Press, 2010, p.17 https://www.nap.edu/catalog/12954/precise-geodetic-infrastructure-national-requirements-for-a-shared-resource

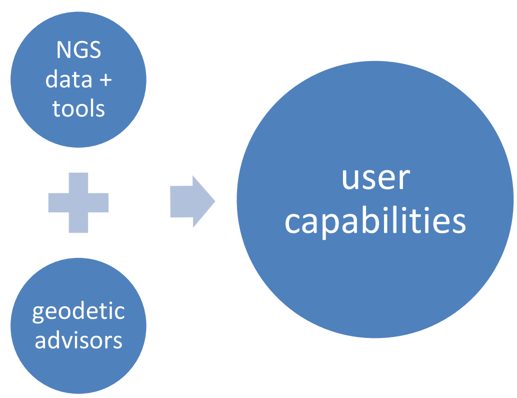
Introduction and Summary

Introduction

The mission of the National Geodetic Survey (NGS) is: "…to define, maintain, and provide access to the National Spatial Reference System (NSRS) to meet our Nation's economic, social and environmental needs."[2] The NSRS includes thousands of reference points whose position is known precisely for use in determining positions at other locations and an extensive network of Continuously Operating Reference Stations (CORS). NGS provides structures for referencing geospatial information and tools for incorporating location data into those systems.[3]

The National Academy of Sciences 2010 report on precise geodetic infrastructure stated:

> "The committee found that one of the 'weakest links' in the implementation of a precision geodetic infrastructure was a lack of trained workforce to develop and maintain the infrastructure in the coming decades. Skilled workers are needed to obtain the highest level of accuracy from the Precise Geodetic Infrastructure, assess the capabilities of the infrastructure as it continues to evolve, and capitalize on advances in technology to improve the accuracy of (or decrease the cost of) the infrastructure."[4]



The Regional Geodetic Advisor Program (RAP) furthers NGS' objectives by providing training and assistance to users of the NSRS to facilitate proper use of modern positioning technologies, NGS geodetic data and tools, and federal positioning standards. The purpose of this scoping study is to provide a preliminary assessment of the nature of the Regional Geodetic Advisor Program and its benefits to the nation.

This study seeks to address the following prescribed questions:

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[2] https://geodesy.noaa.gov/INFO/WhatWeDo.shtml

[3] NSRS is part of the National Spatial Data Infrastructure. The Federal Geographic Data Committee defines the National Spatial Data Infrastructure as: "the technology, policies, standards and human resources necessary to acquire, process, store, distribute and improve utilizations of geospatial data." Federal Geographic Data Committee, *National Spatial Data Infrastructure Strategic Plan, 2014-2016*, p.2, December 2013 https://www.fgdc.gov/nsdi-plan/nsdi-strategic-plan-2014-2016-FINAL.pdf

[4] National Academy of Sciences, *Precise Geodetic Infrastructure: National Requirements for a Shared Resource*, National Academies Press, 2010, pp.107-108 https://www.nap.edu/catalog/12954/precise-geodetic-infrastructure-national-requirements-for-a-shared-resource

1. Who benefits from NGS products and services, and programs?
2. What is the nature of these benefits (how are these benefits accrued)?
3. What methodology(ies) is/are appropriate to best estimate the value of the NGS' products and services, and programs to the users?
4. What are the preliminary estimates of the value for the NGS products and services, and programs?
5. How many jobs do the NGS products and services, and programs support?

Training and assistance takes place in many environments and organizations. The Regional Geodetic Advisor Program is very small in comparison with activities in universities, trade and professional organization meetings and workshops, continuing education venues, and public and private organizations and consulting firms. It also is small in relation to the amount and complexity of geodetic knowledge and in relation to the assistance and outreach efforts of NGS of which it is a part. The challenge is not only to assess the impact of the Regional Advisor Program under these conditions but also to understand ways in which its impact is and can be amplified.

Summary

Regional Geodetic Advisor Program Roles and Nature of Benefits

The Program and Ways It Creates Value

The NGS Regional Geodetic Advisor Program (RAP) is designed to provide technical assistance and training to users of the National Spatial Reference System (NSRS). The core of the program is the NGS Regional Geodetic Advisors who are NGS employees that cover the nation in each of 14 regions. The program began in mid-2016 as a successor to the State Geodetic Advisor Program. RAP encompasses State Geodetic Coordinators (SGCs), typically state employees; and often in transportation departments, who have been assigned and funded by their states to coordinate activities with Regional Geodetic Advisors. In addition, NGS has been developing a group of Geodetic Partners who act as points of contact for Regional Geodetic Advisors and receive and disseminate information about geospatial activities within their areas of interest.

The Regional Geodetic Advisor Program serves a wide range of organizations and individuals who require precise geodetic information. Beneficiaries of the program's training and assistance include professionals in land surveying, construction, engineering design, hydrographic survey, mapping, environmental services, resource management, geo-scientific applications, education and other fields, along with the general public. Regional Geodetic Advisors provide services to NGS as well as to external constituents. RGAs are the primary provider of training for OPUS Projects, the Online Positioning User

Service for post-processing GNSS observations. Other activities involve CORS, the Continuously Operating Reference Station network, and beta testing of new procedures and tools.

Advice and training from Regional Geodetic Advisors can avoid client mistakes in use of reference frames that can impact project quality and can correct mistakes or guide redoing of incorrect work. Regional Geodetic Advisor training can encourage beneficiaries to take advantage of opportunities to increase the precision of their observations and to interconnect reference systems between adjacent projects. Connecting multiple projects to a Geographic Information System (GIS) to get coordinates of a control point makes it unnecessary to determine control points for each project. RGAs provide presentations at national, international and regional conferences and training at state and local survey society and GIS workshops. Advisor presentations at conferences are used to meet some state continuing education requirements for licensing of surveyors. Advisors' efforts create awareness of NGS tools and data and help bring participants to a level at which they can make more effective use of those tools and data. RGAs participate in some state committees that recommend licensing standards, advising on requirements and training needed to meet them. Activities also include assistance to RTNs (Real-Time Networks) in connecting CORS stations to the CORS Network and assistance in establishing calibration baselines. Field work which involves special assignments and one-time efforts beyond usual activities includes assisting the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), the U.S. Bureau of Reclamation (USBR) and other government agencies whose programs have large benefits to the economy and society.

Occupation and Industry Data Shed Light on Constituents

Data on the sizes of occupations and the ways occupations are distributed by industries give a sense of the range of interests and activities of potential clients of the program. State and local governments together accounted for 10.2% of surveyor employment in 2016 and federal government 1.0%, for a government total of 11.2%. In contrast, 37.5% of surveyor employment was in engineering services, including work under contract to governments. 1.2% was in the highway, street and bridge construction industry and 0.7% was in nonresidential building construction, while 40% was scattered among private non-construction industries.

A disproportionate number of surveying and mapping technicians are in local government and self-employment. Cartographers and Photogrammetrists are concentrated in local government and geoscientists except hydrologists and geographers are most numerous in engineering services, management, scientific and technical consulting services and oil and gas extraction. Hydrologists are particularly prevalent in federal, state and local government.

Employment of surveyors was down 22.5% in 2016 from its 2007 level and employment of surveying and mapping technicians was down 25.5%. Employment had not fully recovered by 2016 from the declines of the Great Recession for "Cartographers and Photogrammetrists" and "geoscientists except hydrologists" but did recover for geographers and hydrologists. While increases in productivity may have reduced the need for geospatial professionals in some fields, it is likely that the predominant cause of the declines in employment was the weakness in the economy. Employment in surveying and related occupations generally has not recovered to the same degree as investment spending. This may be the result both of pressures to contain costs persisting from the recession and adoption of technologies that enable the work to be done in less time. Economic growth since 2016 may have led to improvement.

NGS activities have been increasing and RAP activities have risen along with them. Attendance at NGS Geospatial Summits has grown through the years. The numbers of visitors to NGS Web pages grew substantially between 2016 and 2017 in every category. In 2016 there were 2,866 visits to the Regional Geodetic Advisors Web page (https://www.ngs.noaa.gov/ADVISORS/) Visits increased to 4,308 in 2017, the first full year of the program.

Data on NGS Activities and User Surveys Reflect Types of Users, Services Sought and How Services are Used

OPUS static was used for 314,073 cases in FY2016 and OPUS static with solution shared was used for 2,381 cases. OPUS rapid static was used for 129,234 cases. Use of OPUS static has continued to rise.

2,249 OPUS Projects with 6,836 unique marks were created in 2016 by 618 unique users.

373 people were trained in OPUS Projects by 12 RGAs in FY2017, including 254 trained in person and all of the 119 participating in the three Webinars. All but one of the 19 in person OPUS Projects training sessions in FY2017 were conducted by RGAs. RGAs also provide informal, one-on-one OPUS training in their regions. OPUS Projects training has declined in recent years as the pool of those who could benefit from this post-processing service has extensively been served.

Additional insights come from surveys including questions asked of attendees at the NGS 2017 Geospatial Summit and from the Foresee Survey which is administered to individuals who log on to the NGS Website and choose to participate. In the conference survey, when asked what is most critical to support NGS customers, nearly half responded: “validate real time networks.” Interest in increased stakeholder engagement and improve dynamic Web presence also were strong.

In the Foresee Web survey, geodetic quality control is the most frequent use reported, but there are several other land use applications reported as well. Respondents were most often seeking information on CORS/OPUS. Others sought information on data sheets, toolkit software and guidelines or specifications. About 32% of users had contact with NGS staff members, including 10% with a geodetic advisor, 8% with someone on the help desk and 8% with another person in NGS. Assistance from NGS personnel was requested most for recovering survey marks according to responses in the first quarter of 2018 when the question was added. This may reflect the NGS GPS on Bench Marks program.

Survey results for the first quarter of CY2018 show that 38% of site visitors participating in the Foresee survey do training, which multiplies the effects of NGS efforts.

12% of those taking the Foresee survey on the NGS Website were engineers. This is one of a number of indications that those coming to NGS Web sites and conferences have higher skill levels on average than potential clients generally.

Awareness of the change to new geometric and vertical datums was essentially *unchanged* (between 61% and 65%) since 2016. Large numbers of respondents remain unaware and some of those that reported being aware were only "somewhat aware."

Regional Geodetic Advisor services will become even more important if state licensing becomes required for geodesy, which is under consideration. Greatly increased calls for training and assistance (especially for OPUS Projects) can be expected when the new terrestrial reference frames and geopotential datum are introduced in 2022. The recent release of proposed policy and procedures for the State Plane Coordinate Systems and "GPS on Bench Marks" recommendations have already been associated with an uptick in contacts with RGAs.

Preliminary Estimation of Benefits

Estimates of benefits of RGAs are made in two parts: assistance and training for clients and OPUS Projects training for NGS. As of the time of this writing, two Regional Geodetic Advisor positions are vacant, some program personnel are relatively new in their roles and the number of Geodetic Partners is growing. The benefit estimates are scaled to full program capacity and valued in dollars of calendar year 2018 purchasing power.

Value of RGA Assistance to Clients

Preliminary orders of magnitude of the economic benefits of assistance and training provided by Regional Geodetic Advisors to their clients are derived based on benefits of modern geodetic methods over traditional techniques in terms of productivity improvements and cost savings.[5] 45%-55% savings is used based on a review of studies.

A small portion (0.1%) of the benefits of modern methods is used to illustrate the potential magnitude of benefits of RAP activities. 0.1% can be arrived at with many combinations of its components, for example, with 4% of professionals experiencing increases in productivity of 50% for 5% of their activities.

The calculations are carried out for six geoscience occupations and combined. Only the total of geoscience occupations should be relied upon. This portion of the benefit estimates does not include services such as OPUS Projects training or beta testing new products. The results of the calculations are shown in Table S1. Illustrative benefits of services to clients range from $13.2-$23.0 million.

[5] Savings from avoided cost can be used either to reduce costs or to increase output – in which case they are counted as productivity.

Table S1. Illustrative Estimates of Value of Benefits of Regional Geodetic Advisors to their Clients, 2018 (millions of dollars)		
	Number in Occupation	**Benefit Estimates**
Surveyors (including services of survey technicians)	43,340	6.4-11.7
Civil engineers licensed for surveying	1,177	0.1-0.2
Cartographers and Photogrammetrists	12,100	1.2-2.1
Geoscientists except hydrologists and geographers	30,420	4.5-7.4
Hydrologists	6,300	0.9-1.5
Geographers (half)	685	0.1-0.1
Total	**94,022**	**13.2-23.0**

The estimates include contributions of diverse activities including in-person assistance to individuals and organizations, telephone and email assistance, training individuals and groups, field work, assistance to universities, publicizing datum changes and NGS services in networking activities, articles and interviews.

Value of OPUS Projects Training

In addition, an estimate is made of the benefits of OPUS Projects training provided by RGAs based on cost avoidance. The estimate of the value of OPUS Projects training in 2018 is obtained by taking into account the number trained by RGAs, the percent of those trained who are expected to use OPUS Projects in an average year, the number of times OPUS Projects is used by an average user in a year, the average number of marks in each project, and the average value of a resolved mark.

With 314 trained in OPUS by RGAs in 2017, the value of RGA OPUS training is $1.1-$1.2 million.

The combined direct value of RGA activities for clients plus the value of OPUS training in 2018 is on the order of magnitude of $14.3-$24.2 million.

Incorporating Multiplier Effects

A conservative multiplier of 1.3-1.6 is applied to include effects on other industries (expanded estimate). The illustrative expanded combined value of services of RGAs to their constituents and to NGS is $18.6-$38.7 million

Table S-2 summarizes the order of magnitudes of benefits of RGA services to clients and OPUS Projects training with and without multiplier effects.

Table S-2. Illustrative Estimates of Total Benefits of the NGS Regional Geodetic Advisors Program, 2018 (millions)		
	Direct	**Expanded**
RGA services to constituents	$13.2-$23.0	*$17.2-$36.8*
RGA OPUS training for NGS	$1.1-$1.2	*$1.4-$1.9*
Total	**$14.3-$24.2**	***$18.6-$38.7***
Note: The estimates refer to benefits if the program had been operating at full capacity as it is in calendar year 2018.		

Future and Present Discounted Values of Benefits

Next, illustrative scenarios for orders of magnitude of future benefits of the Regional Geodetic Advisor Program are considered. Benefits are projected for each of the ten years 2018-2027 and present discounted values of future benefits are calculated. The value of benefits is discounted to the present to reflect the greater value of immediate benefits than those that are deferred.

One scenario assumes 2% growth in benefits per year to reflect growth of real GDP. The alternative scenario assumes that benefits increase by 4% per year as a result both of improvements in technology which make new methods more valuable in relation to older methods and the growing value of RGA services with the introduction of new terrestrial reference frames and geopotential datum. Benefits are not assumed to grow even faster than 4% because of the historically slow pace at which new reference frames and datum have been adopted and the possibility that RGAs will have to spend more time with each client because of the added complexity with more reference frames and datum.

The U.S. Office of Management and Budget has issued guidance to use a discount rate of 7% above inflation for primary estimates by government agencies.[6] Results of a 4% discount rate are also computed since 4% may be closer to interest rates on Treasury bonds over the period. Results of the calculations are in Table S-3.

[6] U.S. Office of Management and Budget, "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs," Circular A-94, October 29, 1992, p.9 https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf

Table S-3. Present Values of Benefits of the NGS Regional Geodetic Advisors Program (millions of year 2018 dollars)								
	Direct Benefits				Expanded Benefits			
Discount Rate:	4%		7%		4%		7%	
	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range
2% Growth Rate								
Services to Clients	116.5	203.0	100.4	174.9	151.8	324.7	130.8	279.9
OPUS Training for NGS	9.7	10.6	8.4	9.1	12.4	16.8	10.6	14.5
Combined Benefits	126.2	213.6	108.8	184.1	164.1	341.5	141.5	294.4
4% Growth Rate								
Services to Clients	126.9	221.2	108.9	189.8	165.4	353.8	141.9	303.6
OPUS Training for NGS	10.6	11.5	9.1	9.9	13.5	18.3	11.6	15.7
Combined Benefits	137.5	232.7	118.0	199.7	178.8	372.1	153.5	319.3

The 10-year present discounted value of RGA services to clients with the multiplier (expanded) effects included ranges from $130.8 million (with 2% growth and a 7% discount rate) to $372.1 million (with a 4% growth and a 4% discount rate.)[7] Without the multiplier (expanded) effects the range would be $100.4-$222.7 million.

The expanded present discounted value of OPUS training ranges from $10.6-$18.3 million with expanded benefits and from $8.4-$11.5 million without expanded benefits.

The 10-year expanded present discounted value of combined benefits ranges from $141.5-$372.1 million. Without expanded benefits, combined benefits range from $108.8-$232.7 million.

The preferred illustrative estimate of ten-year discounted benefits of the of the Regional Geodetic Advisor Program is for combined benefits with a 4% growth rate and a 7% discount rate. This is a more realistic growth rate of benefits and a more conservative discount rate. On this basis a preliminary present value of combined expanded benefits is $153.5-$319.3 million and without the multiplier it is $118.0-$199.7 million.

Impacts of the Program on Jobs

Cost savings from the use of modern technologies can reduce the number of jobs in geospatial occupations. However, the decline in the cost can lead to a greater amount of activity. Lower cost also reduces the cost of activities that rely on geospatial information, potentially leading to more of them. Modern technologies can make measurement more accurate and reliable which also can increase its use. Abstracting from cyclical influences, the effects of increasing use of modern geospatial methods

[7] The discounted values in the Excel NPV formula treats the benefits as occurring at the end of each year rather than evenly throughout the year.

have not had a noticeable positive impact on the overall number of jobs in associated fields from 2007 through 2016 and may even have had a negative effect. Net impacts may have been positive in the stronger economy since 2016, so the impact for 2007- 2018 is taken to be flat.

Potential Strategic Opportunities

1. NGS has many potential ways of leveraging the RAP in approaches currently in use and others noted, so that it reaches more clients or produces greater impacts. The program needs take advantage of the whole range of opportunities to **leverage outcomes**, so users can fully benefit from its current capabilities and advances in data and tools. Some candidates for explicit emphasis are in italics.

    - Use of the Internet and social media and email lists
    - Speaking to large groups including trade and NGS national and state conferences, NGS Testing and Training Center, state and local government workshops
    - *Field activities (special assignments) of RGAs with potentially high payoffs*
    - *Training people who train others and/or make decisions about training of others; i.e. training the trainers*
    - Assistance in bluebooking benchmarks which provide reference points for use by others
    - *Giving attention to training in situations with insufficient supplies of personnel or skills that can prevent activities from moving forward*
    - *Emphasizing training or assistance to projects that potentially have large economic multiplier effects such as infrastructure construction projects*
    - Promoting licensing requirements for geodesists and participating in or supporting state committees determining licensing requirements
    - *Training and assistance, the results of which results are embedded in forms that can be used by many others without the presence of an RGA. Examples include maps, software, databases, curriculums and manuals*
    - Working with colleges and universities to encourage appropriate curriculum

2. While RGAs give disproportionate attention to government, users are in an increasingly diverse set of occupations and industries. This suggests that RAP and NGS explore possibilities for obtaining greater benefits from their assistance by **modifying the emphasis given to different fields and sectors**. Developing a strategy for doing so requires increased understanding of the needs of each sector and type of user, how those needs are currently being met and how they might be met. Elements that could be considered some that are in the list of ways of leveraging the program, e.g.:

- Giving extra attention to assistance and training in situations with insufficient supplies of personnel or skills that can prevent activities from moving forward
- Emphasizing training or assistance to projects that potentially have large economic multiplier effects such as infrastructure construction projects where additional knowledge or information could reduce project delays and affect others along the value chain

3. NGS could consider tailored **regional versions of notification emails** and/or converting the notifications to an email newsletter with regional versions. The Material could include information of interest to specific industry sectors. Regional Geodetic Advisors could contribute content of regional interest.

Possibilities for More Extensive Analysis of the RAP

1. **The Future of the NGS and RGA Service Needs and Responses:** The types of users of the National Spatial Reference System has been increasing and a major change in reference frames and geopotential datum is being implemented by NGS. As a result, the NGS and the Regional Geodetic Advisor Program will face a future in which they will have to serve more constituents with an increasing variety and complexity of backgrounds and needs. It would be worthwhile to anticipate and explicitly project scenarios for changes in clientele and NGS product needs and consider ways NGS and the Regional Geodetic Advisor Program can contribute to meeting those needs.

> It would be worthwhile to anticipate and explicitly project scenarios for changes in clientele and NGS product needs and consider ways the Regional NGS and the Geodetic Advisor Program can contribute to meeting those needs.

2. **Estimating Benefits of RGA Field Activities**: *A* promising subject for further benefit estimation is the field activities of RGAs, many of which may have high payoffs. In this context field activities refers to special assignments and one-time efforts beyond usual activities. Even a partial estimate including the most important of these could give an additional sense of the value of the RAP and be useful in allocating effort. It may be possible to include some safety-of-life and environmental benefits in such case studies. Field activities of RGAs include working with state and local partners on large projects, helping RTN networks set up CORS stations and helping with calibration baselines, serving as project managers for large projects, helping if there is a new procedure such as river crossing, and providing on-the-ground training and updated guidelines for USGS, USACE, USBR and other government organizations.

> A promising subject for further benefit estimation is the field activities of RGAs, many of which may have high payoffs.

3. **Examining Ways of Leveraging Efforts of NGS and RAP**: It would be useful to systematically examine current and potential methods of leveraging the program through the many current and potential ways that were previously discussed. Among these are training people who train others or determine training for their staff, offering training in situations where insufficient supplies of personnel or skills are preventing activities from moving forward, and emphasizing training or assistance to projects that potentially have large economic multiplier effects – such as infrastructure construction projects.

It would be useful to systematically examine the current and potential methods of leveraging the program which have been noted.

Regional Geodetic Advisor Program Description

The Program

The NGS Regional Geodetic Advisor Program (RAP) is designed to provide technical assistance and training to users of the National Spatial Reference System (NSRS). The core of the program is the NGS Regional Geodetic Advisors who are NGS employees that cover the nation in each of 14 regions. The program began in mid-2016 as a successor to the State Geodetic Advisor Program. The state program was half funded by the states and peaked at 26 states participating. 13 of the 14 Regional Geodetic Advisor positions were filled as of Spring 2018 and the 14th will be filled in the Fall, bringing the program essentially to full capacity.[8]

RAP encompasses State Geodetic Coordinators (SGCs), typically state employees and often in transportation departments, who have been assigned by their states to coordinate activities with Regional Geodetic Advisors. State Geodetic Coordinators devote a portion of their time to assuring that modern geodetic methods are more fully and properly used. 20 states had State Geodetic Coordinators as of February 1, 2018.

In addition, NGS has been developing a group of Geodetic Partners who, whether in the public, academic or private sectors, are interested in staying informed about NGS products and methods, acting as points of contact for Regional Geodetic Advisors, and receiving and disseminating information about geospatial activities within their areas of interest. There were 10 Geodetic Partners as of February 1, 2018 with more expected.

Roles and Duties of Regional Geodetic Advisors

The NOAA Regional Geodetic Advisor Position Description designates the position as:[9]

> "A federal employee of NOAA's National Geodetic Survey (NGS). The employee serves as a liaison between NGS and its public, academic and private sector constituents within their assigned region. They provide expert guidance and assistance to these constituents who are managing the geodetic component of geospatial activities that are tied to the National Spatial Reference System (NSRS). Geodetic advisors serve as subject matter experts in geodesy and regional geodetic issues, collaborating internally across NGS and NOAA to further the organizations' missions. They are to maintain awareness of current developments in geodetic science and technology, updates and improvements to geodetic reference systems, and application to geospatial activities."

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[8] Full capacity allows for normal amounts of unfilled capacity and does not require 100%.
[9] U.S. National Oceanic and Atmospheric Administration, National Ocean Service, "ACS Position Description, Regional Advisor, update, Geodesist," March 7, 2017.

According to the Regional Geodetic Advisor Project Plan: "The RAP is the primary means of outreach to all NGS constituents. The Regional Advisors are the people that interact with all types of organizations and provide training and presentation at many local, state, national and international events."[10]

Duties of Regional Geodetic Advisors are described as follows:

- "Advisors will provide assistance and support to the development and use of CORS, OPUS, Height Modernization, referencing static control to NSRS, assistance with reference frame issues such as new datum realizations and geoid models, etc.
- The Regional Advisor will help serve as a conduit of information to users, including things like disseminating information about important technical developments at NGS.
- Each Regional Advisor should encourage users to subscribe to the NGS news list-serve.
- The Regional Advisor should help facilitate and advertise NGS training webinars.
- The Regional Advisor should endeavor to become involved in state-level organizations focused on geospatial issues; such involvement will engage and keep informed key GIS managers.
- The focus of advisor activities should be consistent and in sync with the NGS ten-year plan and the associated implementation plans/project plans."

Roles and Duties of State Geodetic Coordinators

In its information page on roles and responsibilities for the three types of participation, NGS describes the State Geodetic Coordinator position as follows:[11]

> "The Coordinator serves as a liaison between the state and NGS. NGS will not be involved in the selection process but will acknowledge the position when notified by a state agency recognized for their statewide interest in geodetic activities and connecting such activities to the NSRS. The selection criteria are determined by their affiliate agency/organization, but they should include having the broad support of the state's geospatial community and expertise in geodesy, surveying, engineering or a related field. The roles and responsibilities are also determined by their affiliate agency/organization, but they should include using their technical expertise in geodesy to make informed decisions about and provide guidance for geospatial activities that benefit from connection to the NSRS. The State Geodetic Coordinator is a primary point of contact for the Regional Geodetic Advisor."

[10] U.S. National Oceanic and Atmospheric Administration, National Geodetic Survey, NOAA's "National Geodetic Survey Regional Geodetic Advisor Project Plan," Version 4.1, September 2015 (internal), p.17.

[11] U.S. National Oceanic and Atmospheric Administration, National Geodetic Survey, information page on roles and responsibilities for the three types of participation in the Regional Geodetic Advisor Program, June 17, 2017 (internal).

Beneficiaries and Nature of Benefits of the Program

Regional Geodetic Advisor Activities and Beneficiaries

The Regional Geodetic Advisor Program serves a wide range of organizations and individuals who require precise geodetic information. Beneficiaries of the program's assistance and training include professionals in land surveying, construction, engineering design, hydrographic survey, mapping, environmental services, GIS, geo-sciences, education and other fields as well as the general public. The magnitudes of potential occupations and industries that provide or make use of geospatial information and the sizes of activities of NGS personnel and Regional Geodetic Advisors are detailed in the footprint analysis.

RGAs receive telephone and email inquiries directly and address questions referred by the central NGS Information Service. In some cases, inquiries are followed up with presentations to groups at the client's venue. RGAs make presentations at many professional and trade associations at the national, regional and state levels. Presentations typically emphasize basics of geodesy, NGS products, and new developments. These conferences deliver fundamental knowledge that leads some participants to learn more, use NGS products or request assistance. They provide visibility and networking opportunities for RGAs which lead to further calls for training and assistance. RGAs provide expertise to those developing licensing legislation and educational curriculum. RGAs also provide a variety of assistance to organizations in field activities.

Regional Geodetic Advisors provide services to NGS as well as to external constituents. RGAs are the primary provider of training for OPUS Projects, the Online Positioning User Service for post-processing observations. Other activities for NGS involve CORS and beta testing of new products.

Nature of the Benefits

Advice and training from Regional Geodetic Advisors can avoid mistakes in use of reference frames that can impact project quality as well as correct mistakes or guide redoing of incorrect work. Assistance may be requested by someone who is doing something new and/or requires help in converting datums or using new NGS products. People may either request assistance proactively or after problems arise.

Regional Geodetic Advisor training can encourage beneficiaries to take advantage of opportunities to increase the precision of their observations and to interconnect reference systems between adjacent projects. Connecting to a GIS system makes it unnecessary to determine control points separately for each project, which can mean substantial savings in survey time and cost. This kind of assistance typically has been for state and local governments who manage multiple projects, sometimes across several departments.

> *One interviewee stated that training private surveyors provides tremendous cost savings if it results in work being done properly in the field so the person who collects the data draws the site diagram. Otherwise someone in the office doing the drawing must determine which features the points are associated with when multiple interpretations are possible. He stated that the savings are especially great when there is a change from older to newer equipment.*

RGAs provide presentations at national, international and regional conferences and provide training at state and local survey society and GIS workshops when requested and as resources and time allow. They also create awareness of NGS tools and data products and help bring participants to a level at which they can make more effective use of those tools and data.

RGAs participate in some state committees that recommend licensing standards, advising on requirements and training needed to meet them. Regional Geodetic Advisor services will become even more important if state licensing becomes required for geodesy – which is under consideration and which NGS encourages.

Activities of RGAs include assistance to RTN networks in establishing CORS and assistance in calibration baselines and getting coordinates established. RGAs work with USGS, USACE and USBR when there is a new procedure such as a river crossing for which they may provide on-the-ground training and updated guidelines.

Field work which involves special assignments and one-time efforts beyond usual activities includes assisting the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), the U.S. Bureau of Reclamation (USBR) and other government agencies whose programs have large benefits to the economy and society. One advisor helped the U.S. Coast Guard validate accuracy before they set buoys. Recently RGAs served as project managers for a large subsidence project in Southern Louisiana and provided on-site OPUS training for the Bureau of Land Management.

NGS will introduce "NAPGD2022," the "North American-Pacific Geopotential Datum of 2022," along with four new terrestrial reference frames. OPUS will provide access to the reference frames and the geopotential datum. Efforts to familiarize the community with the change are underway and a template has been drafted for updating existing state laws.[12] Greatly increased calls for training and assistance can be expected when the new geopotential datum and reference frames are introduced. The recent release of impact to State Plane Coordinate Systems and "GPS on bench mark" recommendations has already been associated with an uptick in contacts with RGAs.

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[12] U.S. National Oceanic and Atmospheric Administration, National Geodetic Survey, *2017 Geospatial Summit: Modernizing the National Spatial Reference System*, NOAA Special Publication NOS NGS 12, Silver Spring, April 24-25, 2017 https://www.ngs.noaa.gov/library/pdfs/SP_NOS_NGS_12.pdf

Footprint Analysis of Beneficiaries

The footprint analysis examines the size and composition of potential types of clients and their interests and use of NGS services.

National Occupation Data

This section considers U.S. Bureau of Labor Statistics data on the numbers of employed persons in occupations of interest and their distribution by industry. Definitions of occupations are in Appendix B.

Table 1 and Figure 1 examine employment of surveyors by industry in 2016. The largest category of surveyor employment by far was in engineering services at 37.5%. Adding in those in management, scientific, and technical consulting services, self-employed workers, those in other specialty trade contractors and those in temporary help services brings the total of consulting and contingent workers to 42.8%. This includes those under contract to governments.

In contrast, state and local government together account for 10.2% of surveyor employment, including those who oversee private contractors, and federal government 1.0%, for a government total of 11.2%. 1.2% were in the highway, street and bridge construction industry and 0.7% were in nonresidential building construction, while 40% were scattered among private non-construction industries. A disproportionate number of surveying and mapping technicians are in local government and self-employment.

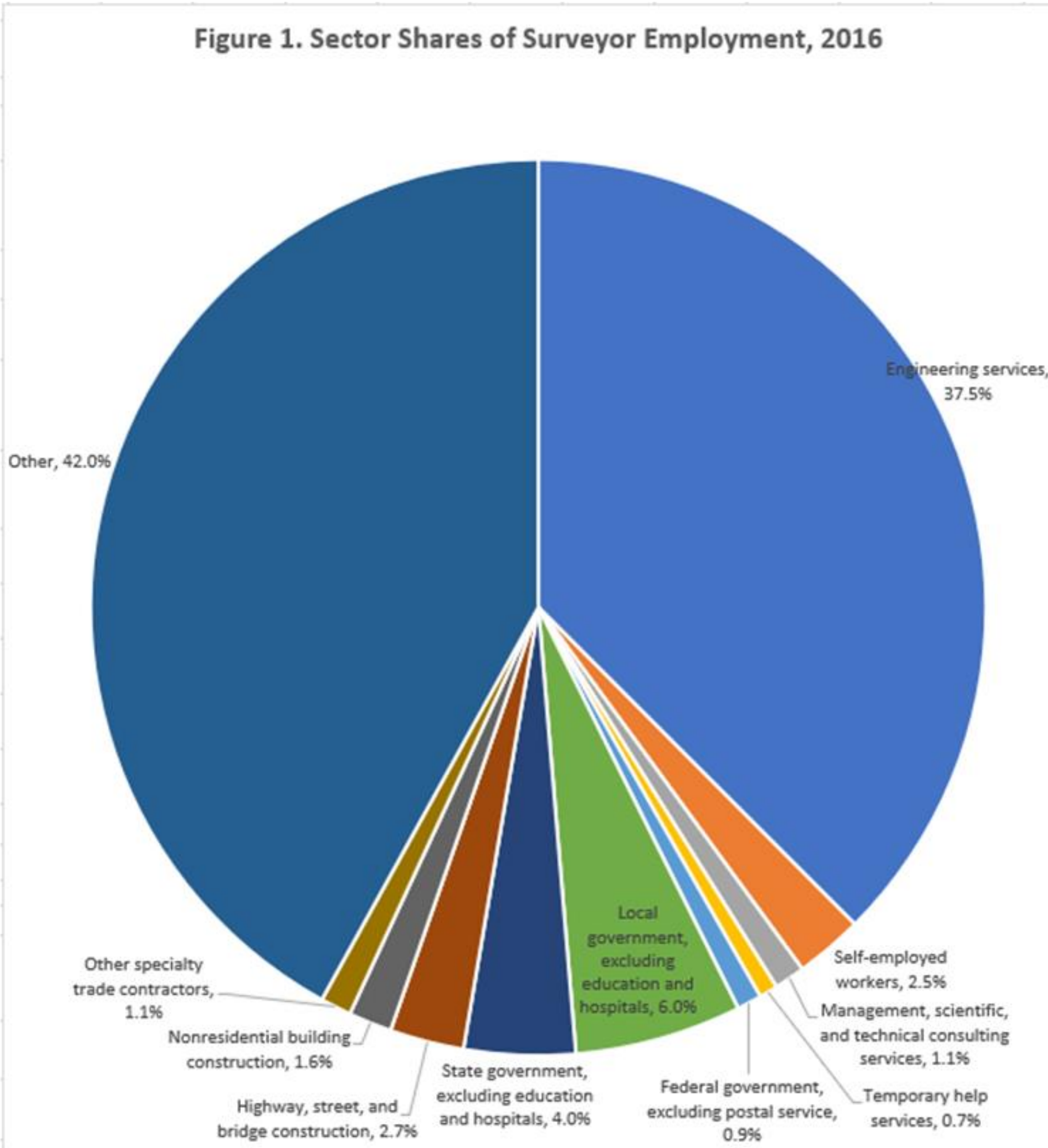
Distributions by industry also were examined for other geoscience occupations. A disproportionate number of surveying and mapping technicians are in local government and self-employment (Table 1). Hydrologists are particularly prevalent in federal, state and local government (Table 2). Cartographers and photogrammetrists are concentrated in local government while geoscientists except hydrologists and geographers are most numerous in engineering services, management, scientific and technical consulting services and oil and gas extraction (Table 3 and Figure 2).

The diverse industries which many in these occupations serve raises the question of whether the Regional Geodetic Advisor Program might consider differentiated outreach strategies for serving 1) government, 2) consulting and similar activities, 3) construction and 4) those spread among other private sectors, individually or as a whole.[13]

[13] It would have to be determined whether services of management, scientific, and technical consulting services, self-employed, other specialty and trade contractors, other support services and temporary help services would best be considered together with the engineering services category, with those spread throughout other private sector categories, or segmented into those largely working for governments.

Table 1. Employment of Surveyors and Surveying and Mapping Technicians by Industry, 2016

		Surveyors		Surveying and Mapping Technicians	
Industry	**Industry Code**	**Employment** (thousands)	**Percent of Occupation**	**Employment** (thousands)	**Percent of Occupation**
Total employment		**44.8**	**100.0**	**53.9**	**100.0**
Engineering services	541330	16.8	37.5	14.6	27.1
Local government, excluding education and hospitals	999300	2.7	6.0	6.6	12.2
State government, excluding education and hospitals	999200	1.8	4.0	1.4	2.6
Highway, street, and bridge construction	237300	1.2	2.7	0.2	0.4
Self-employed workers	TE1100	1.1	2.5	5.5	10.2
Nonresidential building construction	236200	0.7	1.6	0	0.0
Other specialty trade contractors	238900	0.5	1.1	0.3	0.6
Management, scientific, and technical consulting services	541600	0.5	1.1	0.8	1.5
Federal government, excluding postal service	999100	0.4	0.9	0.9	1.7
Temporary help services	561320	0.3	0.7	0.1	0.2
Oil and gas extraction	211000	0.2	0.4	1.1	2.0
Coal mining	212100	0.2	0.4	0	0.0
Support activities for mining	213000	0.2	0.4	0.3	0.6
Power and communication line and related structures construction	237130	0.2	0.4	0.1	0.2
Other heavy and civil engineering construction	237900	0.2	0.4	0	0.0
Management of companies and enterprises	551000	0.2	0.4	0.6	1.1
Metal ore mining	212200	0.1	0.2	0	0.0
Residential building construction	236100	0.1	0.2	0	0.0
Other support services	561900	0.1	0.2	0	0.0
Natural gas distribution	221200	0	0.0	0.6	1.1
Crop production	111000	0	0.0	0.2	0.4
Source: https://www.bls.gov/oes/tables.htm					



Industry distributions for other geoscience occupations are shown in Tables 2-4 and Figure 2. Some highlights are:

- 40.5% of cartographers and photogrammetrists are in state and local government and 5.0% are in the federal government

- 20.7% of geoscientists except hydrologists and geographers are in oil and gas extraction, 3.6% are in support activities for mining, 16.2% are in government and 5.9% are in state colleges, universities, and professional schools
- 30.2% of hydrologists are in the federal government and 20.6% are in state government
- 61.5% of geographers are in the federal government and 7.7% are in state government

12.3% of civil engineers are in state government and 10.6% are in local government.

Table 2. Employment of Hydrologists and Geographers by Industry, 2016

		Hydrologists		Geographers	
Industry	**Industry Code**	**Employment (thousands)**	**Percent of Occupation**	**Employment (thousands)**	**Percent of Occupation**
Total employment		**6.3**	**100.0**	**1.3**	**100.0**
Engineering services	541330	1.1	17.5	0.1	7.7
Local government, excluding education and hospitals	999300	0.6	9.5	0	0.0
State government, excluding education and hospitals	999200	1.3	20.6	0.1	7.7
Self-employed workers	TE1100	0.1	1.6	0.1	7.7
Management, scientific, and technical consulting services	541600	1.3	20.6	0.1	7.7
Federal government, excluding postal service	999100	1.9	30.2	0.8	61.5
Research and development in the physical, engineering, and life sciences	541710	0.1	1.6	0.1	7.7
Source: https://www.bls.gov/oes/tables.htm					

Table 3. Employment of Cartographers and Photogrammetrists and of Geoscientists, Except Hydrologists and Geographers, by Industry, 2016

		Cartographers and Photogrammetrists		Geoscientists, Except Hydrologists and Geographers	
Industry	**Industry Code**	**Employment (thousands)**	**Percent of Occupation**	**Employment (thousands)**	**Percent of Occupation**
Total employment		**12.1**	**100.0**	**30.4**	**100.0**
Engineering services	541330	1.6	13.2	5.8	19.1
Local government, excluding education and hospitals	999300	4.1	33.9	0.2	0.7
State government, excluding education and hospitals	999200	0.8	6.6	2.3	7.6
Self-employed workers	TE1100	0.2	1.7	0.9	3.0
Management, scientific, and technical consulting services	541600	1.3	10.7	4.8	15.8
Federal government, excluding postal service	999100	0.6	5.0	2.4	7.9
Temporary help services	561320	0.1	0.8	0.1	0.3
Oil and gas extraction	211000	0.2	1.7	6.3	20.7
Support activities for mining	213000	0	0.0	1.1	3.6
Management of companies and enterprises	551000	0.5	4.1	1.7	5.6
Metal ore mining	212200	0	0.0	0.4	1.3
Natural gas distribution	221200	0.2	1.7	0	0.0
Fossil fuel electric power generation	221112	0	0.0	0.1	0.3
Testing laboratories	541380	0.1	0.8	0.5	1.6
Computer systems design and related services	541500	0.2	1.7	0	0.0
Colleges, universities, and professional schools; state	611302	0.1	0.8	1.8	5.9
Social advocacy organizations	813300	0.1	0.8	0	0.0
Pipeline transp. of natural gas	486200	0.1	0.8	0	0.0
Software publishers	511200	0.1	0.8	0	0.0
Research and dev. in the physical, engineering, and life sciences	541710	0.1	0.8	0.6	2.0
Petroleum and coal products mfg.	324000	0	0.0	0.2	0.7

Source: https://www.bls.gov/oes/tables.htm

Figure 2. Sector Shares of Employment of Geoscientists Except Hydrologists and Geographers, 2016

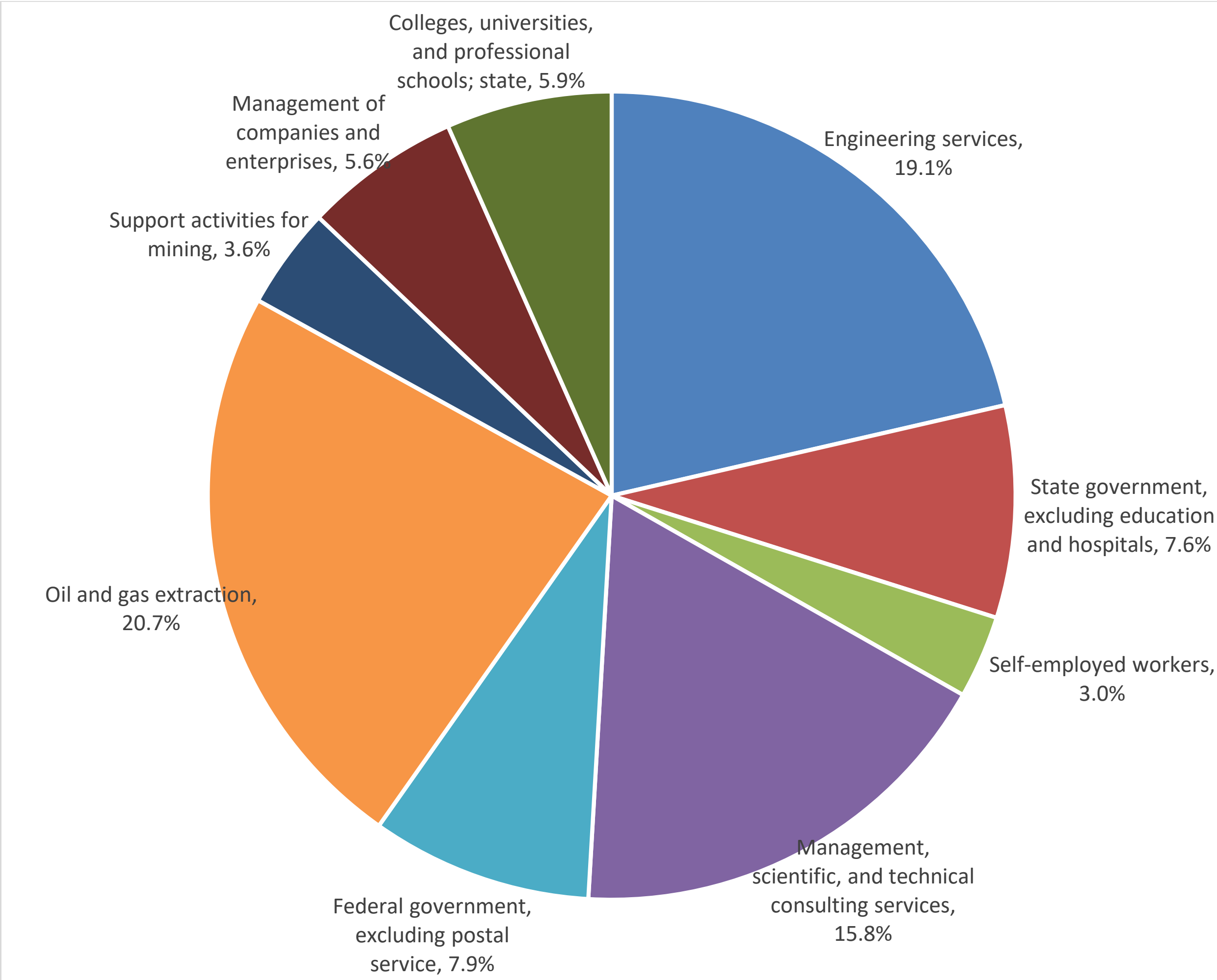


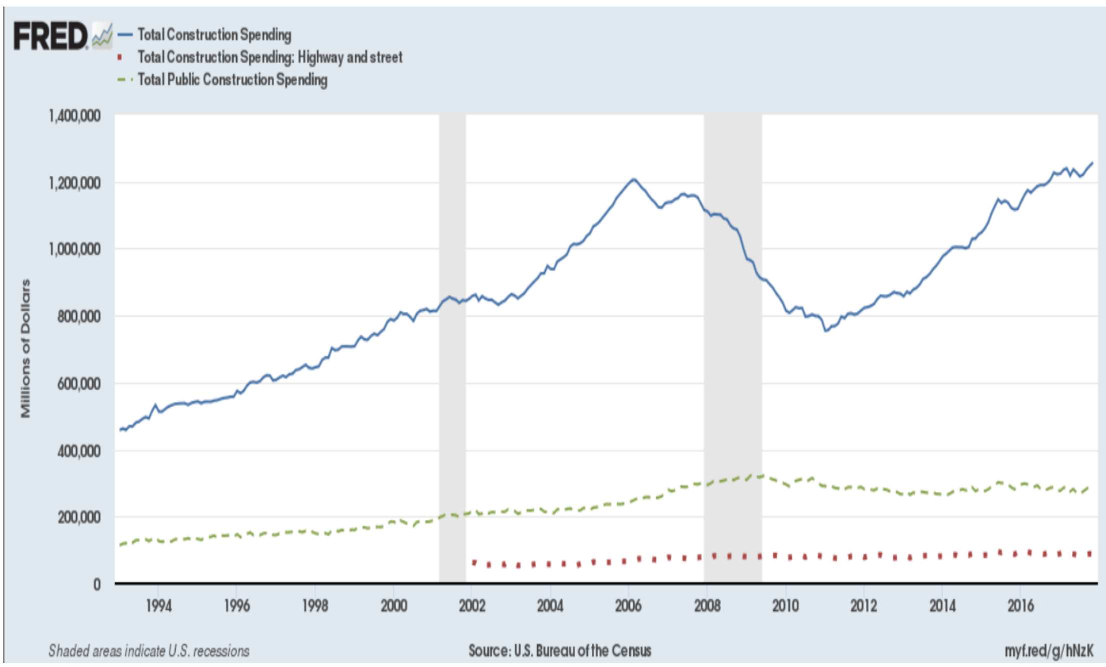
Table 4. Employment of Civil Engineers by Industry, 2016

Industry	Industry Code	Employment	Percent of Occupation
Total employment		**287.8**	**100.0**
Engineering services	541330	146.8	51.0
State government, excluding education and hospitals	999200	35.4	12.3
Local government, excluding education and hospitals	999300	30.5	10.6
Nonresidential building construction	236200	18.7	6.5
Self-employed workers	TE1100	10.2	3.5
Federal government, excluding postal service	999100	10.1	3.5
Management, scientific, and technical consulting services	541600	5.8	2.0
Highway, street, and bridge construction	237300	3.3	1.1
Management of companies and enterprises	551000	3.3	1.1
Temporary help services	561320	3	1.0
Other heavy and civil engineering construction	237900	2.5	0.9
Colleges, universities, and professional schools; state	611302	2.2	0.8
Residential building construction	236100	1.2	0.4
Testing laboratories	541380	1.1	0.4
Research and development in the physical, engineering, and life sciences	541710	1.1	0.4
Plumbing, heating, and air-conditioning contractors	238220	1	0.3
Natural gas distribution	221200	1	0.3
Activities related to real estate	531300	0.7	0.2
Other specialty trade contractors	238900	0.6	0.2
Oil and gas extraction	211000	0.6	0.2
Power and communication line and related structures construction	237130	0.6	0.2
Poured concrete foundation and structure contractors	238110	0.5	0.2
Electrical contractors and other wiring installation contractors	238210	0.5	0.2
Architectural and structural metals manufacturing	332300	0.5	0.2
Rail transportation	482000	0.5	0.2
Remediation and other waste management services	562900	0.4	0.1
Source: https://www.bls.gov/oes/tables.htm			

Employment Trends

Table 5 shows trends for the last decade in a range of geospatial occupations.[14] Civil engineers are included because some have been doing surveying and related work. Employment of surveyors was down 22.5% in 2016 from its 2007 level and employment of surveying and mapping technicians was down 25.5%. Employment had not fully recovered by 2016 from the declines of the Great Recession in the categories "cartographers and photogrammetrists" and "geoscientists except hydrologists" but did recover for geographers and hydrologists.

Figure 3. Construction Spending

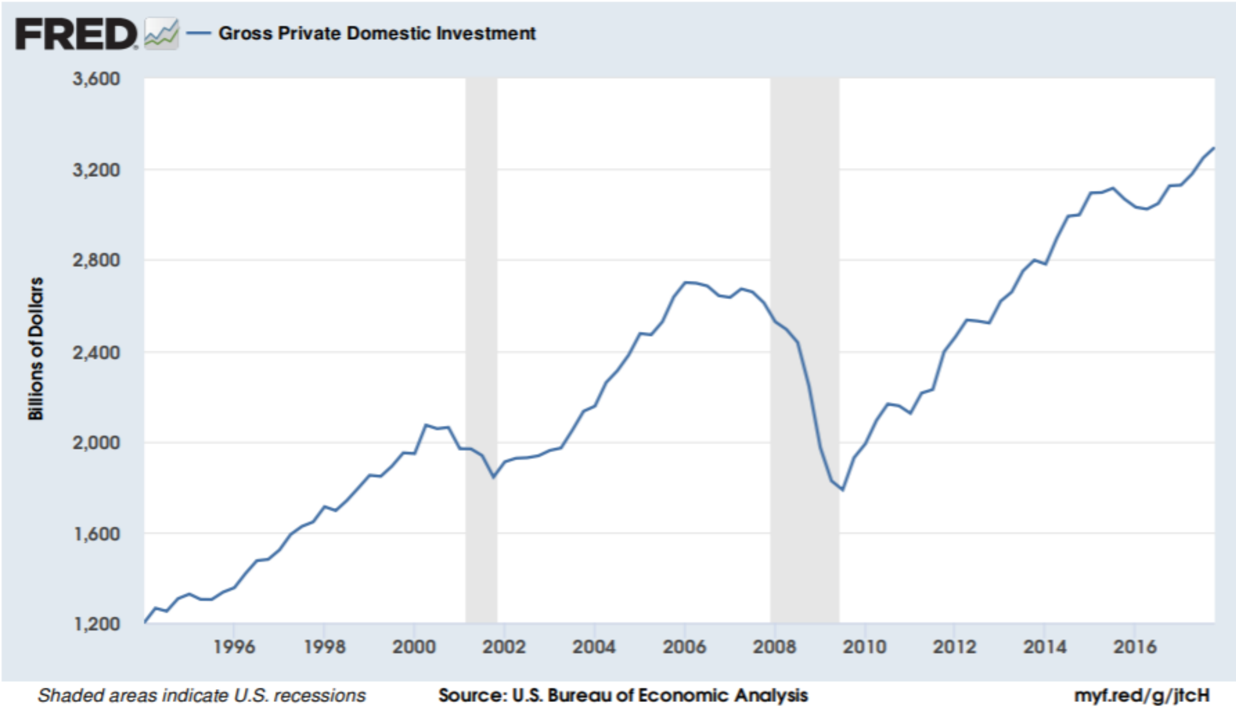


While increases in productivity may have reduced the need for surveyors and survey technicians, it is likely that the predominant cause of the decline in geospatial employment was the weakness in the economy. Central to the decline is the behavior of the construction cycle and capital spending (gross private domestic investment) shown in Figures 3 and 4.[15] Employment in geospatial occupations generally has not recovered to the same degree as investment spending. This may be the result of both pressures to contain costs persisting from the recession and adoption of technologies that enable the work to be done in less time.

[14] The 2017 αlphaβeta study for Google found that 770,000 jobs in the U.S. were directly related to the provision of geospatial services or technologies in the geospatial sector (broadly defined, including applications, and including satellites). This is far more than the numbers in occupations directly related to surveying and associated skills shown in the BLS data. αlphaβeta, *The Economic Impact of Geospatial Services: How Consumers, Businesses and Society Benefit from Location-Based Services*, September, 2017, p.54 http://www.alphabeta.com/wp-content/uploads/2017/09/GeoSpatial-Report_Sept-2017.pdf

[15] The two graphs are courtesy of the Federal Reserve Bank of St. Louis Federal Reserve Economic Database (FRED) https://research.stlouisfed.org/datatools.html The data are not adjusted for inflation.

Figure 4. Gross Private Domestic Investment



Growth in employment has continued for civil engineers. However, civil engineering is too large a category to indicate trends in surveying activities among engineers. Data from the National Council of Examiners for Engineering and Surveying indicates that about 5,884 persons who were dual engineers and surveyors took state licensing exams in 2015 vs. 55,475 surveyors, putting dual engineers and surveyors at 9.6% of the total of the two categories. In 2016 the number of dual engineers and surveyors taking the exam was 5,313 and the number of surveyors 51,091, with dual accreditation accounting for 9.4% of the total.[16]

[16] National Council of Examiners for Engineering and Surveying, *2016 Squared*, pp.24-27 http://2016.nceesannualreport.com/wp-content/uploads/sites/4/2016/02/Squared-2016.pdf and National Council of Examiners for Engineering and Surveying, *2017 Squared* https://ncees.org/wp-content/uploads/Squared-2017-web.pdf In states without a breakdown between residents and nonresidents, numbers were allocated to states based on the proportion of residents among residents and nonresidents in the total of states for which it was available.

Table 5. Employment by Occupation, 2007-2016

Occupation	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Surveyors	56,670	55,780	50,360	43,950	42,020	40,190	41,360	41,970	43,140	43,340
Surveying and mapping technicians	72,410	71,920	62,940	53,870	48,590	47,000	47,950	50,750	53,620	53,920
Cartographers and photogrammetrists	11,460	11,690	11,750	11,670	11,240	11,490	11,290	11,610	11,970	12,100
Geoscientists, except hydrologists and	31,390	31,260	31,860	30,830	32,490	35,180	34,690	34,000	31,800	30,420
Hydrologists	7,670	7,590	7,150	6,910	6,960	6,880	6,540	6,580	6,580	6,300
Civil engineers	247,370	261,360	259,320	249,120	254,130	258,100	262,170	263,460	275,210	287,800
Geographers	1,010	1,120	1,170	1,300	1,430	1,510	1,480	1,260	1,280	1,370
Foresters	10,510	10,160	10,230	9,470	9,000	9,470	9,220	9,140	8,590	8,420
Forest and conservation technicians	26,900	30,850	31,440	32,290	30,620	31,720	29,740	30,310	29,810	30,090
Geological and petroleum technicians	13,060	14,570	14,460	13,560	14,680	15,360	15,190	16,020	16,820	15,100
Mining and geological engineers, including mining safety engineers	7,150	6,900	6,310	6,270	6,630	7,640	7,990	8,200	8,000	6,940
Source: https://www.bls.gov/oes/tables.htm										

In 2015 dual engineering and surveying licensees represented 0.67% of the nearly 900,000 engineers and in 2016 0.60%, so even a small shift in the proportion of engineers doing surveying could result in a substantial increase in the numbers of professionals doing surveying. However, there is little indication that engineers have been increasing their role in surveying and related areas. Some training in surveying takes place in university civil engineering departments. Growth in interest in surveying among engineers for at least one relatively small application area is suggested by the fact that the Utility Engineering and Surveying Institute (UESI) of the American Society of Civil Engineers (ASCE) held a 2018 Surveying and Geomatics Conference on April 22-April 24, 2018 in Pomona, CA. This is the first ASCE conference related to surveying since 1992.

Employment also increased between 2007 and 2016 for geographers, foresters and geological and petroleum technicians.

Table 6 shows U.S. Bureau of Labor Statistics projections of employment growth through 2026 by occupation. Projections of this kind are difficult and should not be viewed as very reliable, but they do give an indication of the thinking of labor force experts based on what is known at the time. For surveyors and surveying and mapping technicians, growth is projected at only about 1% per year, while

Table 6. Employment Growth Projections, 2016-2026

	2016 (thousands)	2016-2026 change	percent change
Surveyors	44.8	5.0	11.2
Surveying and mapping technicians	60.2	6.4	10.6
Cartographers and Photogrammetrists	12.6	2.4	19.4
Geoscientists, except hydrologists and geographers	32.0	4.5	13.9
Hydrologists	6.7	0.7	9.9
Civil engineers	33.2	1.3	3.8
Geographers	1.5	0.1	6.2
Forest and conservation technicians	33.2	1.3	3.8
Geological and petroleum technicians	15.0	2.5	16.4
Mining and geological engineers, including mining safety engineers	7.3	0.5	7.2
Source: https://www.bls.gov/oes/tables.htm			

larger increases are projected for "cartographers and photogrammetrists" and for "geoscientists except hydrologists," a category that includes geodesists.

Industry Data

The U.S. Census Bureau collects extensive data on industries, but the level of detail is insufficient to include many of the activities of interest. The Economic Censuses provide revenue and employment for private surveying and mapping firms, the last data from which was for 2012. The Geophysical and other than geophysical revenue of private surveying and mapping firms is shown as published for 2002 and 2012 in Table 7. The years are at roughly comparable points in the business cycle. The data is not adjusted for inflation. Industry definitions vary among censuses. The latest are in Appendix A.

Table 7. Revenue of Private Surveying and Mapping Firms, 2002 and 2012
(millions of dollars)

	2002	2012
Geophysical	1,188	3,151
Other than geophysical	4,659	5,848
Total	**5,758**	**8,999**

Source: U.S. Economic Censuses, 2002 and 2012.

Economic Censuses are conducted every five years. One was conducted in 2012 and the next will have data for 2017. However, the data for private surveying and mapping firms from the 2017 Economic Census is not expected to be available until at 2020 or 2021.

NGS Program Data

The NGS Information Center staff answers questions from emails and telephone inquiries and routes questions to subject matter experts when the information center staff does not have the technical expertise. Some of the referred queries are handled by Regional Geodetic Advisors. The NGS Information Center records handling about 1,200 inquiries per year which may be a significant undercount, according to NGS staff. Data is not available on how many of those inquiries were routed to RGSs or how many requests were sent to the NGS Information Center by RGAs.

In 2016 there were 2,866 visits to the Regional Geodetic Advisors Web page. Visits increased to 4,308 in 2017, the first full year of the program.

Large numbers of people visit NGS Web pages. The numbers of visitors increased substantially between 2016 and 2017 in every category. (The counts include multiple visits by the same person.) Many visitors went directly to subject pages. 171,275 visited the CORS page in 2017. 9,016 visited the page for height modernization in the period while 4,078 visited the pages for the publications library and 4,018 visited the NGS Testing and Training Center (Corbin) training calendar (Table 8).

In 2016 there were 2,866 visits to the Regional Geodetic Advisors Web page. Visits increased to 4,308 in 2017, the first full year of the program.

Table 8. NGS Web Page Visits, 2017

URL	Page Title	Visits
/ADVISORS/index.shtml	NGS Regional Geodetic Advisors	4,308
/INFO/subscribe.shtml	NGS Subscription Services	518
/heightmod/	Height Modernization Entire Section all pages	9,016
/heightmod/index.shtml	Height Modernization Landing page only	1,599
/web/science_edu/presentations_library/	Presentation Library	2,928
/PUBS_LIB/pub_index.html	Publications	4,078
/corbin/calendar.shtml	Calendar of Upcoming Classes	4,018
/INFO/conferences.shtml	Upcoming and Recent Events	1,974
/web/science_edu/webinar_series/Webinars.shtml	Recent Webinars	2,359
/web/science_edu/webinar_series/archived-webinars.shtml	Archives Webinars	1,405
/web/science_edu/webinar_series/user-forums-qa.shtml	User Forums and Q&A Sessions (each of the 4 pages linked)	56
/corbin/class_description/OP_Forum_060717.shtml	OPUS Projects User Forum	108
/corbin/class_description/OP_Forum_1116.shtml	OPUS Projects User Forum June 7, 2017	104
/corbin/class_description/OP_Forum_0716.shtml	OPUS Projects User Forum July 12, 2016	113
/web/science_edu/webinar_series/CORS_QA.shtml	CORS Questions and Answers Session September 29, 2015	66
/corbin/class_description/opus-projects-manager-training-videos.shtml	OPUS Projects Manager's Training Videos	334
/CORS/	CORS Entire Section all pages	171,275
/CORS/index.shtml	CORS Landing page only	72,249

The main NGS Web page under "Contact Us" has a link at the bottom to "Subscribe for email notifications." Clicking on the link leads to a page to sign up for NGS News emails (occasional), NGS

Webinar Series monthly notice of monthly presentations on NGS programs, projects, products and services, and/or NGS Training email announcements. In FY 2017, subscriptions to NGS email newsletters and announcements grew by 39 for NGS News, 29% for NGS training and 49% for NGS Webinars, reaching about 1,000 each. (Table 9).

Table 9. Subscriptions to NGS Email Newsletters and Announcements, FY2017

	Subscriptions	FY2017 Net Change	Percent Change, FY2016-FY2017
NGS News	961	373	39%
NGS Training	1,371	400	29%
NGS Webinars	1,030	509	49%

NGS holds occasional Geospatial Summits to update constituents on current and future developments. Table 10 shows the numbers of attendees at the summits in 2010, 2015 and 2017. Attendance increased through the years.

> More than half of nonfederal attendees at the 2017 NGS Geospatial Summit were from private organizations.

97 of the 436 attendees in April 2017 were from NGS while another 59 were from NOAA. The largest attendance outside of NOAA was from USGS. Participation by USACE has fallen off, apparently because of stepped up efforts at training within the organization. State government department attendance numbered 65 in 2017, far less than the federal government. The great majority of attendees from state governments were in a category: “other than department of transportation or unspecified state government organization.”

County and local governments also had a significant number of attendees. More than half of nonfederal attendees at the 2017 NGS Geospatial Summit were from private organizations.

OPUS, the Online Positioning User Service, consists of OPUS Share which is also known as OPUS static, OPUS rapid static and OPUS Projects (see Text Box 1). OPUS static was used for 314,073 cases in FY2016 and OPUS static with solution shared was used for 2,381 cases. OPUS rapid static was used for 129,234 cases. Use of OPUS static has continued to rise.

2,249 OPUS Projects with 6,836 unique marks were created in 2016 by 618 unique users.

RGAs conduct OPUS Projects training, usually at a facility provided in a state. Webinars are provided from RGA regional offices with technical support from the NGS Testing and Training Center. These are in addition to RGA regional responsibilities.

Table 10. Affiliations of 2017 NGS Geospatial Summit Attendees

Affiliation	2010	2015	2017
Federal government total	**200**	**158**	**216**
NGS	56	81	97
NOAA other than NGS	37	12	59
USGS	7	6	14
USACE	21	12	4
USDA	9	0	2
Military other than USACE	13	8	4
Other federal government	57	39	36
State government	**12**	**56**	**65**
State Department of Transportation	2	29	19
Other than DOT or unspecified state government	10	27	46
County and local government	**1**	**15**	**23**
Educational	**9**	**22**	**16**
Private	**43**	**140**	**115**
International	**4**	**1**	**1**
TOTAL	**269**	**392**	**436**

Source: U.S. National Oceanic and Atmospheric Administration, National Geodetic Survey, 2017 Geospatial Summit: Modernizing the National Spatial Reference System, NOAA Special Publication NOS NGS 12, Silver Spring, April 24-25, 2017 https://www.ngs.noaa.gov/library/pdfs/SP_NOS_NGS_12.pdf

385 people participated in OPUS Projects training in FY 2017 in 22 sessions which included 19 in person sessions and three Webinars. 266 were trained in person and 119 in Webinars. The number of users and projects has been declining as the pool of those who could benefit from this post-processing service has largely been served and other methods such as RTK have taken hold.

373 were trained by RGAs, including 254 in person and all of the 119 participating in the three Webinars. All but one of the 19 in person OPUS training sessions in FY2017 were conducted by RGAs. 12 RGAs conducted training in FY2017, with five sessions conducted by multiple RGAs. RGAs also provide some informal, one-on-one OPUS training in their regions.

OPUS Projects training has declined in recent years along with the decline in the number of users and number of projects in the population (Table 11). Once trained, people can continue to use the service on their own. The availability of Webinars does not explain the decline in OPUS training demand since the use of Webinars has not been growing. Both the number of sessions and average class size have been affected.

Text Box 1. OPUS Share and OPUS Projects

OPUS Share (OPUS static)

Online Positioning User Service (OPUS) provides simplified access to high-accuracy National Spatial Reference System (NSRS) coordinates for a single site. Users upload a GPS data file collected with a survey-grade GPS receiver and obtain and NSRS position via email. Coordinates are either average from 3 independent, single-baseline solutions (OPUS static) or processed using more aggressive algorithms to resolve carrier phase ambiguities (OPUS rapid-static).

OPUS Projects

OPUS Projects it gives users web-based access to simple management and processing tools for projects involving multiple sites and multiple occupations. The advantages of OPUS Projects are:

- Data uploading through OPUS.
- Customizable data processing via the PAGES software suite.
- Visualization and management aids.

Use of OPUS Projects is restricted to trained project managers.

Table 11. OPUS Projects Training, FY2014-FY2017

Fiscal Year	In-Person		Webinar	
	Number of Sessions	Number Trained	Number of Sessions	Number Trained
2014	71*	1160*	n.a.	n.a.
2015	28	566	3	59
2016	29**	436**	5	157
2017	19	266	3	119

*Includes one session reported as "virtual."
**Includes an on-site session for the U.S. Bureau of Land Management.

Many presentations are available online in the NGS Presentation Library https://www.ngs.noaa.gov/web/science_edu/presentations_library/ Unlike Webinars, these do not include audio or video. The list is not a complete collection of all presentations by NGS personnel. The Presentation Library includes 74 presentations in 2017 of which 24 were by RGAs, one of which was jointly by an RGA and another presenter and 49 of which were by others.

Regional Geodetic Advisors each handle about eight questions per month from the NGS Information Center https://geodesy.noaa.gov/INFO/NGSinfo.shtml according to available information.

Client Surveys

2017 Geospatial Summit

The 2017 Geospatial Summit on April 24-25 surveyed both in-person and Webinar participants on each day.[17] These included significant numbers of NGS and other NOAA personnel. In the April 24 survey most respondents were either land surveyors (34%) or "researchers or geodesists" (26%) while 7.4% were engineers.

56% stated that online tools were most critical to support NSRS users while 25% chose "bluebooking and data sheets." Fewer than one in 10 selected field operations, shoreline surveys or airport surveys. When asked what is most critical to support NGS customers, nearly half responded "validate real time networks." Interest in increased stakeholder engagement and improve dynamic Web presence also were relatively strong (Table 12).

Table 12. What Is Most Critical to Support NGS Customers?

Type of Support	Number of Responses	Percent of Responses
Validate real time networks	97	46.9
Increase stakeholder engagement	31	15.0
Increase university engagement	12	5.8
Improve dynamic Web presence	38	18.4
Expand educational portfolio	11	5.3
Support Integrated Ocean and Coastal Mapping (OCM)	18	8.7
Total	**207**	**100.0%**

Source: Responses to question on April 24, 2017 at the NGS 2017 Geospatial Summit https://www.ngs.noaa.gov/library/pdfs/SP_NOS_NGS_12.pdf

Foresee Survey

The Foresee survey provided additional perspectives on NGS user needs and preferences. The Foresee Survey is a Web survey administered to individuals who log on to the NGS Website and choose to participate. It consists both of regular questions and special questions which may continue for a few months to a couple of years. Some of the data drawn upon in this analysis dates back to 2016. Some questions of interest are several years old and are not discussed.

[17] U.S. National Oceanic and Atmospheric Administration, National Geodetic Survey, *2017 Geospatial Summit: Modernizing the National Spatial Reference System*, NOAA Special Publication NOS NGS 12, Silver Spring, April 24-25, 2017 https://www.ngs.noaa.gov/library/pdfs/SP_NOS_NGS_12.pdf

It is not known how representative the self-selected respondents are, either of visitors to the NGS Website or of the broader population of potential NGS clients.

At the request of this study, NGS added three questions to the Foresee Web Survey in late December (Text Box 2). Three months are generally required to obtain a sufficient sample size for analysis. The first results which are reported here are from late December 2017 through the end of March 2018.

Text Box 2. Questions Added to Foresee Survey for This Study

1. On what topics have you requested assistance from NGS personnel during the last two years? (select all that apply)

a. Planning a survey

b. Recovering survey marks

c. Assistance with online tools or programs

d. General geodesy or remote sensing concepts or terminology

e. Upcoming changes to geodetic reference frames

f. Other

g. NA

2. Which of the following describes your interactions with NGS personnel during the last two years? (select all that apply):

a. NGS information center or "help desk"

b. NGS colleague or individual (other than a geodetic advisor)

c. NGS geodetic advisor

d. Other, please specify

e. NA

3. On geospatial topics such as geodesy or remote sensing, do you train others, or determine the training of others, either within or outside of your organization?

a. Yes

b. No

Foresee data for January 2016-March 2018 show that while land surveyors represent a plurality of users, 49%, there is evidence of a statistically significant decline from 56% in 2016 in those who describe their role as land surveyors as a proportion of respondents (Chi-square =217.22, $p<.005$) (Table 13).

The percent taking the survey who are engineers, at 12%, is much higher than the number of engineers taking license exams in surveying as a percent of the number of people in geospatial occupations. This could be the case if engineers do sophisticated work more often than others for which they need additional tools and information.

Table 13. Which Term Best Describes Your Role?

Role	2016 (N=672)	2017 (N=1012)	2018 (N=280)
Land Surveyor	56%	49%	49%
Engineer	12%	12%	12%
Cartographer/GIS Mapping User	7%	9%	9%
Researcher	7%	8%	8%
General Public	5%	6%	5%
Geodesist	4%	6%	5%
Other	4%	4%	4%
Student	3%	3%	4%
Educator	2%	2%	3%
Geocacher	1%	1%	1%
News Media	0%	0%	0%

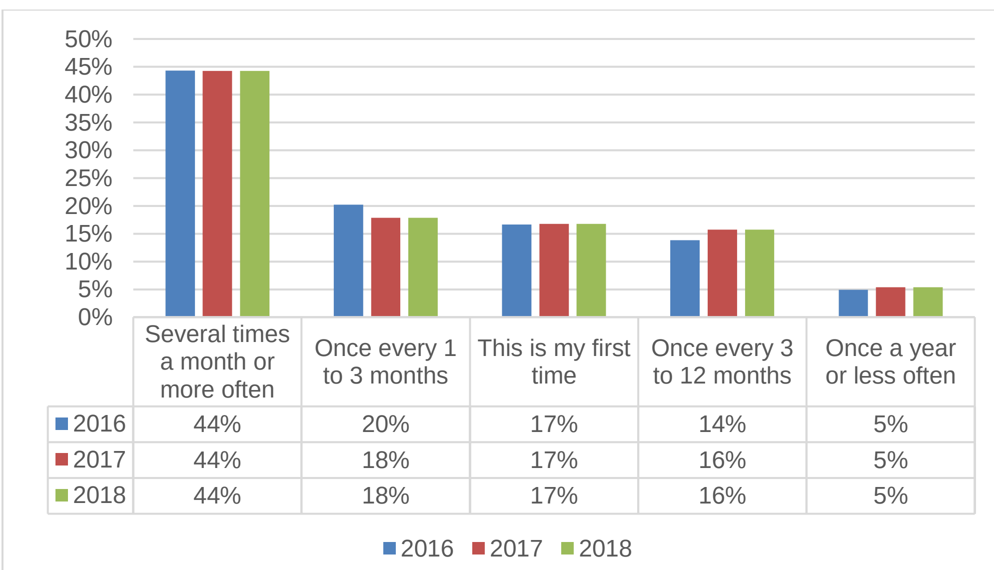
Source: Responses to Foresee Survey, Jan. 2016-March 2018.

Geodetic quality control is the most frequent use reported in the period, but a number of other land use applications are reported as well, including deeds and plats, flood certification, transportation, and construction (Table 14).

Table 14. What Do You Primarily Use NGS Data For?		
Use of NGS Data	**2016** (N=672)	**2017** (N=1003)
Geodetic Quality Control	28%	27%
Deeds, Plats, or Boundaries	17%	17%
Other	14%	15%
Not applicable - I am visiting this site for other reasons	11%	11%
FEMA Flood Certification	10%	9%
Transportation (roads, waterways, bridges, or tunnels)	9%	9%
Construction	7%	8%
Urban Planning	3%	2%
Agriculture and/or Crop Management	1%	1%
Source: Responses to Foresee Survey, Jan. 2016-March 2018.		

The frequency of reporting individuals visiting the NGS site remained constant between 2016 and the first three months of calendar year 2018 (Figure 5).

Figure 5 . How Frequently Do You Visit This Site?



Sample Size: N=672 in 2016, N=1,012 in 2017 and N=280 in 2018 (3 months).

Respondents were most often seeking information on CORS/OPUS. Others sought information on data sheets, toolkit software and guidelines or specifications (Table 15).

Table 15. What Were You Primarily Looking for on This Visit to the Website?

Looking for	2016 (N=672)	2017 (N=1002)	2018 (N=280)
CORS/OPUS	47%	43%	40%
Datasheets	21%	17%	22%
Toolkit software	11%	12%	11%
Other	10%	10%	10%
Guidelines or specifications	7%	9%	10%
Imagery/LIDAR	2%	8%	5%
News	2%	2%	3%
Source: Responses to Foresee Survey, Jan. 2016-March 2018.			

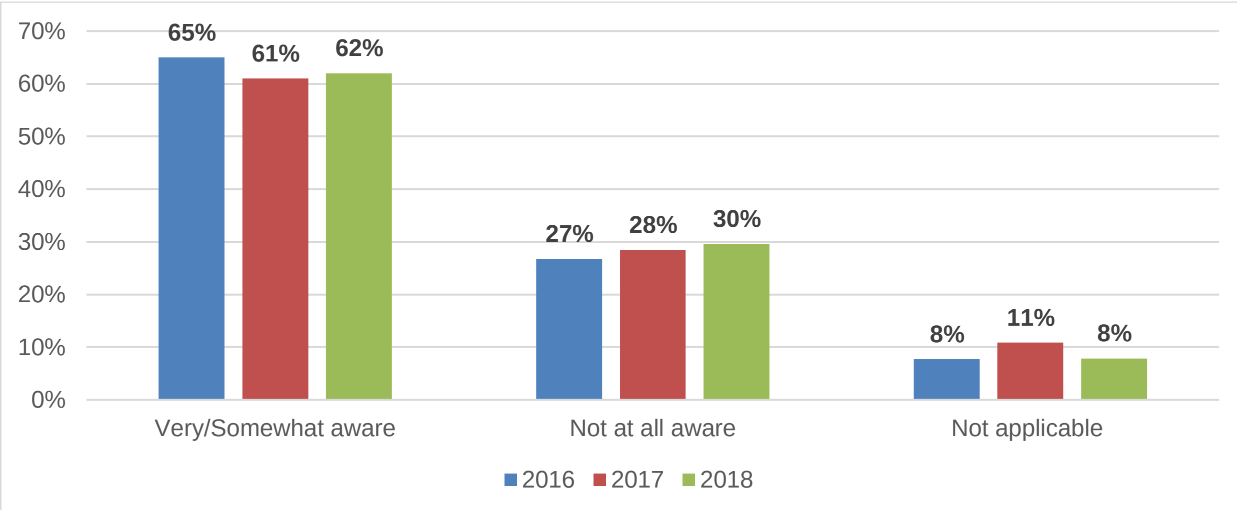
Several formats are acceptable for learning about geodetic practices and methods. Three-fifths are self-service in nature, including web-based videos and slides and published manuals and articles (Table 16).

Table 16. What Are Users Preferred Learning Formats?

Preferred Learning Format	2016 (N=672)	2017 (N=1002)
Web accessible videos, slide shows (no interaction with instructor)	37%	38%
Workshops and conferences	26%	24%
Guidelines, user manuals, and published articles	21%	22%
Live Web conference (interactive with instructor)	9%	9%
Other	4%	6%
NGS' training center in Corbin, VA (now called the NGS Testing and Training Center)	3%	1%
Source: Responses to Foresee Survey, Jan. 2016-March 2018.		

Awareness of the change to new geometric and vertical datum was essentially *unchanged* (varying between 61% and 65%) since 2016 (Figure 6). Large numbers of people remain unaware and some of those that reported being aware were only "somewhat aware."

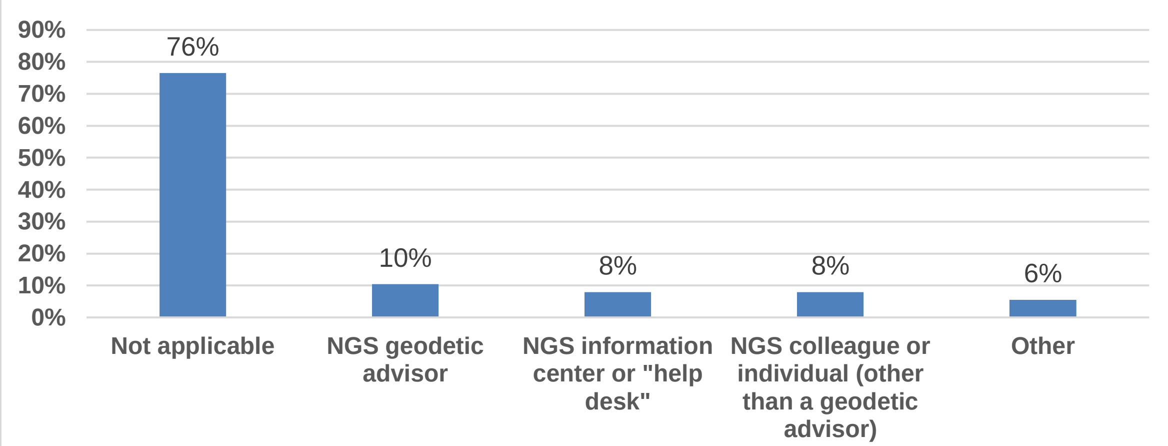
Figure 6. Awareness that NGS Will Replace NAVD 88 with New Geometric and Vertical Datum



Sample Size: N=672 in 2016, N=1,012 in 2017 and N=280 in 2018 (3 months).

About 32% of respondents had contact with an NGS staff member, including *10% with a geodetic advisor*, 8% with someone on the help desk and 8% with another person in NGS (Figure 7).

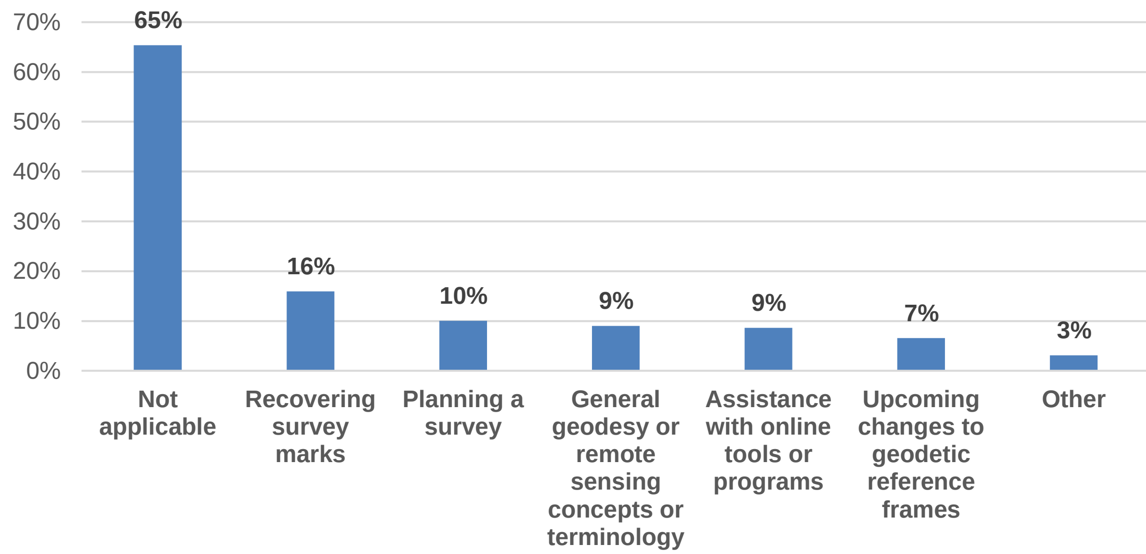
Figure 7. Have You Interacted with NGS Personnel During the Past Two Years? (n=289)*



Assistance from NGS personnel was requested most on recovering survey marks (Figure 8). This may reflect the NGS GPS on Bench Marks program (GPSBM). However, since this question was initiated in the first quarter of 2018, it is not possible to test how much the answers are affected by the introduction of GPSBM.

The topics on which assistance was requested from NGS include planning a survey, general geodesy or remote sensing information, and assistance with online tools. Seven percent inquired about upcoming changes to geodetic reference frames.

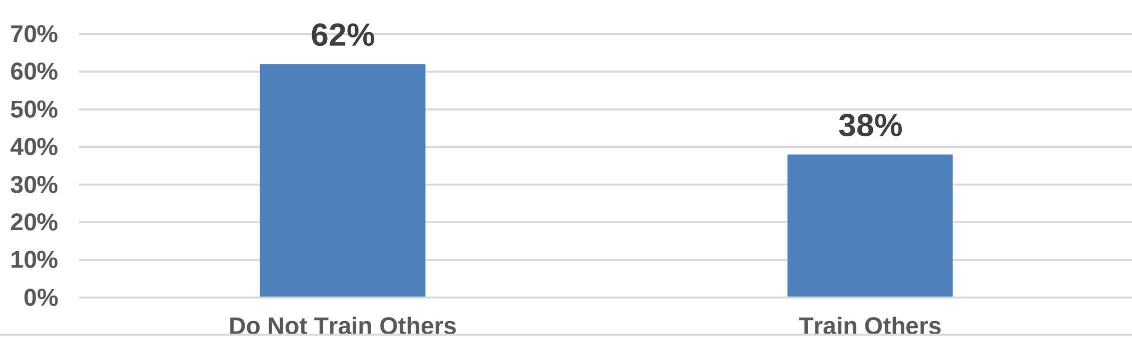
Figure 8. On What Topics Have You Requested Assistance from NGS Personnel in the Past Two Years? (N=289)*



*Data collected between 12/27/2017 and 3/31/18.

A key to effective outreach is reaching trainers who will, in turn, upgrade skills of others and/or keep their skills up-to-date. Survey results from the first quarter of calendar year 2018 show that 38% of site visitors participating in the survey do training, which multiplies the effects of NGS efforts (Figure 9).

Figure 9. Do you Train Others Or Determine the Training of Others in Topics Such as Geodesy or Remote Sensing? N=289*



*Data Collected between 12/27/2017 and 3/31/18.

Approach and Methodology for Assessing the Value of the Program

Approach

A wide range of NGS and external sources of information were accessed to examine the activities of RGAs and their relation to other NGS activities and to understand the communities of users of NGS services. NGS personnel provided extensive data on utilization of NGS services, user surveys and information on the RAP program and NGS. Additional information was obtained from the NGS Website.

Interviews were held with Regional Geodetic Advisors, a State Geodetic Coordinator and knowledgeable people in the industry. A detailed list of questions was prepared for each category from which questions were selected for discussions and interviews. These sources helped to understand the nature of the benefits of the program and how they are achieved. Examples of questions are included in an appendix.

Identifying Impacts

- The preferred basis of economic benefits is improved outcomes. Benefits are measured based on what would have been expected to occur in the absence of the program
- A wide range of ways of measuring benefits is possible. Choice of measures depends on the data and resources available and the nature of activities.
    - For organizations and programs, outcomes may include avoided cost, reduced cost, increased productivity and/or increased capabilities of organizations.
        - Reduced or avoided cost from the introduction of more efficient methods and increased productivity are equivalent in the sense that the lower cost per unit of production can be used either to spend less or to use the savings to increase output.
    - Other measures are appropriate when studying effects on the population such as willingness to pay, cost of time saved and impacts on home values.
- Direct outcomes may have indirect and induced effects on supplying and using sectors. These “multiplier effects” can be very difficult to measure, especially when they are the result of new and/or fundamental or “behind the scenes” technologies. The need for defensible results suggests choosing values for multiplier effects conservatively.

Estimation Methods

Preliminary orders of magnitude of benefits of RGA services to clients are illustrated by taking a percentage of the gain in benefits of modern over traditional methods, drawing on results of a wide range of studies which are discussed in the next section of this report. The benefit estimate is made by:

The benefit estimates are made by:

1. Beginning with the numbers of professionals potentially using NGS services in six occupations. Services of survey technicians were incorporated in the estimated for surveyors by inclusion in overhead. For engineering, only civil engineers were included and only the 20% estimated to be licensed in surveying were included. Half of geographers were included assuming some of their work benefits less often from modern geodetic methods

2. Assuming a range of average cost in each occupation, including associated staff and overheads, building on examination of annual earnings

3. Multiplying the number of professionals in each occupation by average cost to derive a range for total cost

4. Assuming modern geodetic techniques reduce costs (or increase productivity) over traditional methods, on average, by 45%-55%. This is based on a review of studies in the previous section. The use of 45%-55% is supported by evidence for occupations accounting for most of the activity. The calculation assumes the same percentages for each occupation, but the focus is on the total of geospatial occupations.

5. Calculating what the cost would have been without modern methods based on the percentages of improvements in cost

6. Multiplying the percentages of savings from modern methods by the cost without modern methods to obtain a range of estimates of cost saving for each profession

7. Assuming benefits from RGA activities of 0.1% of costs savings from use of modern geodetic methods. The same percentage was used for each occupation. 0.1% can be arrived at with many combinations of its components, for example, with 4% of professionals experiencing increases in productivity of 50% for 5% of their activities

Benefits are computed based on 2016 occupation data which is the latest available. Average costs in each occupation are taken to be for 2018, with the resulting benefit estimates for 2018.

As of the time of this writing, two Regional Geodetic Advisor positions are vacant, some program personnel are relatively new in their roles and the number of Geodetic Partners is growing. The benefit estimates are scaled to full program capacity.

In addition, an estimate is made of the benefits of OPUS Projects training provided by RGAs based on cost avoidance. The estimate of the value of OPUS Projects training in 2016 is obtained by taking into account the number trained by RGAs, the percent of those trained who are expected to use OPUS Projects in an average year, the number of times OPUS Projects is used by an average user in a year, the average number of marks in each project and the average value of a resolved mark.

A multiplier is applied to the results of the two estimates to include effects on the rest of the economy. Illustrative scenarios for future benefits are considered and present discounted values of future benefits are calculated. The present discounted values of streams of benefits over ten years are calculated for alternative future growth rates of benefits and discount rates, with and without multiplier effects.

Estimation of the impact on jobs allows for influences in both directions. Cost savings from the use of modern technologies reduce the number of geospatial jobs. However, the decline in cost can lead to a greater amount of activity. Lower cost also reduces the cost of activities that rely on geospatial information, potentially leading to more of them. Modern technologies can make geospatial information more accurate and reliable which can increase its use. Nevertheless, the effect of the cost reduction may be too large to have been offset by the other influences. The net outcome is an empirical question which is based on data rather than on theoretical considerations.

A jobs multiplier need not be identical to a multiplier applied to output since increased activity can be associated with a different ratio of jobs to output than existing activity due to differences in cost structure of the increase and/or in skill mix.

Studies of Geospatial Benefits

Many studies have demonstrated the value of modern geodetic tools in reducing cost and improving productivity. These have dealt with horizontal and vertical positioning in applications ranging from surveying and mapping to photogrammetry to geosciences and covered impacts on many economic sectors.

The National Height Modernization Study

The 1998 Height Modernization Study examined the benefits of using GPS technology for height surveys instead of conventional methods.[18] The study considered avoided costs, comparing the new GPS technologies with traditional leveling that would be used in their absence. Sixteen case studies of two types were conducted: 1) post-analysis of existing height survey projects, and 2) controlled test surveys using each of the methods (legacy vs. GPS) in the same location. The report observed that: "The modernized NSRS is easier to maintain and 10 to 100 times more accurate in the horizontal dimension that the present system." While the use of the data in drawing some of the study's conclusions is subject to question,[19] the individual estimates of percentage improvement are valuable.[20] Moreover, technological advances since 1998 have brought greater savings and wider applicability.

Large benefits were found throughout the cases examined.

> "The cost savings from using GPS versus conventional leveling ranged from 25 percent to more than 90 percent. Cost savings were greatest when distances (> 4km) existed between survey points.... GPS is particularly effective when geodetic control must be quickly established in disaster areas where the local geodetic infrastructure [monuments] has been largely destroyed, when a project involves large areal coverage, or when difficult, rugged terrain lies between survey points."[21]

The study reported variable cost savings but did not include fixed costs. If fixed costs were included the impacts would be somewhat lower. However, great advances in geodetic tools have occurred since the

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[18] Dewberry & Davis and Psomas & Associates, *National Height Modernization Study: Report to Congress*, Washington, DC: National Oceanic and Atmospheric Administration, National Geodetic Survey, June 1998 http://www.ngs.noaa.gov/PUBS_LIB/1998heightmodstudy.pdf

[19] Irving Leveson, *Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D*, prepared for the National Geodetic Survey, National Oceanic and Atmospheric Administration, January 2009, pp.34-35 www.ngs.noaa.gov

[20] *Ibid*, p.xiii.

[21] Dewberry & Davis and Psomas & Associates, *National Height Modernization Study: Report to Congress*, Washington, DC: National Oceanic and Atmospheric Administration, National Geodetic Survey, June 1998, p.xix http://www.ngs.noaa.gov/PUBS_LIB/1998heightmodstudy.pdf

time of the study and are not reflected in the estimates. Results of the case studies were summarized as shown in Table 17.

Table 17. Variable Cost Savings from GPS In Surveying	
Post hurricane elevation surveys	90%
Post-earthquake elevation surveys	66%
Water district elevation surveys	75%
Crustal motion monitoring	99%
Subsidence monitoring	45%-75%
GPS RTK construction surveys	26%-71%
County and city-wide 3D control surveys	26%-80%
Topographic mapping for reservoir construction	71%
Source: Dewberry & Davis and Psomas & Associates, *National Height Modernization Study: Report to Congress*, Washington, DC: National Oceanic and Atmospheric Administration, National Geodetic Survey, June 1998, p.4.1.	

The Scoping Study of NSRS, CORS and GRAV-D Benefits

A 2009 scoping study by Leveson for the National Geodetic Survey (NGS) made tentative estimates of the value of the benefits of the National Spatial Reference System (NSRS).[22] The NSRS consists of more than 1,500,000 survey marks established through public and private cooperation to provide accurate horizontal and/or vertical position information, along with 1,300+ Continuously Operating Reference Stations (CORS) which NGS coordinates and monitors. The study found illustrative order of magnitude benefits of NSRS of $2.4 billion per year. This was derived by building on revenue from private surveying and mapping, adding assumptions for the government and not-for-profit sectors and adding a factor for societal benefits. The $2.4 billion per year, extended over 15 years and discounted at 7%, would lead to a present value for NSRS of $22 billion. If benefits grew at 7% per year, the discounted value would be $36 billion.

Richard Snay of NGS (now retired) estimated the benefits of CORS at $643 million in fiscal year 2008 based on assigned values per download of each type.[23] The value per basic download was conservatively based on earlier information from the U.S. Army Corps of Engineers on the cost of driving to an existing geodetic reference station, setting up equipment, observing two hours of data and returning to the office. The Leveson scoping study refined the estimates by adjusting to account for the fact that not all

[22] Irving Leveson, *Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D*, prepared for the National Geodetic Survey, National Oceanic and Atmospheric Administration, January 2009 www.ngs.noaa.gov The discussion in this section is adapted from that study.

[23] Richard Snay, October 3, 2008 email to NGS personnel.

users would be willing to pay the full cost of obtaining data from a station and adding an assumed factor for societal benefits. The order of magnitude of CORS benefits was thus estimated as $758 million per year. The present value of these benefits, discounted at 7% over 15 years, is $6.9 billion even without future growth. If benefits grew at a 15% annual rate, the order of magnitude of the present value of CORS benefits over the next 15 years would be $18.5 billion.

The study also made illustrative estimates of the added value of Gravity for the Redefinition of the American Vertical Datum (GRAV-D), a system being implemented that provides more accurate elevation estimates through CORS as part of the National Spatial Reference System. One important application of elevation information is in determining in which direction water will flow. Benefits were calculated based on avoided costs of conducting long line leveling surveys and from improved floodplain management. The value was found to be $522 million per year if the system was available under then current conditions. This resulted in an illustrative estimate of the present value of benefits of GRAV-D over 15 years of $4.8 billion. The study noted that while the costs of maintenance of the underlying information are relatively low, they also would have to be taken into account.

Other U.S. Studies

The Wisconsin height modernization program started with a pilot study that began in 1998 and continued with monumentation, leveling, GPS surveys and processing of adjustment data for submission to the NSRS. The program was reported in November 2004 to have findings that included the following:[24]

- "An 83% reduction in costs to counties in conducting quality control of photogrammetry products they receive" that translated into a projected savings of $1.5 million once there would be statewide coverage.

- "An 89% reduction in costs of WisDOT [Wisconsin Department of Transportation] in determining the location of photogrammetric targets placed in the field for control of planning and design of highway construction and reconstruction projects" that when projected statewide would result in annual savings of $1.25 million for the 100 projects completed each year.

In another example of survey benefits, pilot height measurements were taken at a unit of the Milltown Reservoir Sediments/Clark Fork River Superfund site in Montana, alternatively using static GPS methods and using height modernization enhanced methods.[25] The modernized methods utilized Real Time Kinematic (RTK) GPS. A first-order vertical High Accuracy Research Network (HARN) system was used as a proxy since a Virtual Reference System (VRS) was not available. Total survey costs were lower by 83% with the enhanced methods compared to a traditional static GPS survey, a cost of $800 vs. $4,700. Survey time was lower by 81%. A traditional non-GPS survey would have cost $8,600.

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[24] Wisconsin Department of Transportation, "Wisconsin Height Modernization Program," November 2004 http://ngs.woc.noaa.gov/heightmod/publications.shtml

[25] Montana Department of Transportation, Height Modernization – Pilot Project," January 9, 2007.

In a comparison published by Caterpillar, two identical roads were built, one using stakes in the ground and the other using Machine Control AccuGrade systems. Machine control resulted in productivity gains of 23%-32% in earthmoving operations and from 7% to 71% in grading, while providing greater accuracy and saving 43% in fuel.[26]

Canadian Studies

Klatt estimated the value of the Canadian Spatial Reference System Precise Point Positioning Service (CSRS-PPP).[27] CSRS-PPP provides free access to the national standard for positioning through post-processing of GNSS data to improve accuracy from meters to centimeters. The service fills the gap in the large parts of Canada that do not have reasonable access to monumented survey control.

Klatt's estimate is relative to use of commercial services and passive reference stations. Estimates were made for July 1, 2014-June 30, 2015 based on updating and refining the FY2008 avoided cost estimate made by Richard Snay which was used in the 2009 Leveson Consulting study.[28] The earlier estimate was validated by Klatt by disaggregating domestic use into five use cases which were examined and through formal and informal interviews. The average use of CSRS-PPP was valued at C$1000 in 2015 which is equivalent to US$780 based on the exchange rate on March 12, 2018.

The 2015 Canadian Geomatics Environmental Scan and Economic Value Study commissioned by Natural Resources Canada's Mapping Information Branch, in collaboration with the Canada Centre for Remote Sensing and the Surveyor General Branch was carried out by Hickling Arthurs Low in partnership with ACIL Allen Consulting, Fujitzu Canada and ConsultingWhere.[29,30]

The study found:

- Firms in the private geospatial sector contributed $2.3 billion to Canada's GDP in 2013. The sector includes location-based services, broadly defined.

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[26] Malaga Demonstration & Learning Center, "Road Construction Production Study," Caterpillar, December 2006.

[27] Klatt, Calvin, "Estimating Benefits to Canada and the World: The Canadian Spatial Reference System, Precise Point Positioning Service," *Geomatica*, September 6, 2017 http://pubs.cig-acsg.ca/doi/abs/10.5623/cig2017-104

[28] Leveson Consulting , *Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D*, January 2009 http://www.ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf

[29] Hickling Arthurs Low, *et. al.*, Canadian Geomatics Environmental Scan and Value Study, Summary Report, Prepared for Natural Resources Canada, March 22, 2015 http://ftp2.cits.rncan.gc.ca/pub/geott/ess_pubs/296/296426/cgdi_ip_41e.pdf

[30] Previous studies which have estimated benefits of geospatial activities to the U.S. and the world that have provided interesting information but less useful aggregate estimates of benefits are the BCG study which provided an insufficient description of its methodology, and the Oxera study. These are: Boston Consulting Group, "Putting the U.S. Geospatial Services Industry On the Map," slides, BCG, December 2012, p.3 http://www.ncge.org/files/documents/US-FullReport.pdf and Oxera Consulting, Ltd., *What Is the Economic Impact Of GEO Services?*, Prepared for Google, 2013 http://www.oxera.com/Oxera/media/Oxera/downloads/reports/What-is-the-economic-impact-of-Geo-services---summary_2.pdf

- Geospatial information use resulted in $20.7 billion in additional GDP, an increase of 1.1% of GDP, 19.6 million additional jobs and a $2.8 billion increase in the net trade surplus.[31]

Bernknopf *et*. *al*. examined exploration efficiency and effectiveness in finding exploration targets with updating and improved resolution in bedrock geological maps.[32] For one Canadian site, an updated courser resolution updated map resulted in finding 60% more targets for mineral exploration and an exploration campaign that would be 44% more efficient. Refining the map resolution resulted in a 17% reduction in search effort across all favorable domains and a 55% reduction in the most favorable domain. At another site the value of the updated map ranged from CAN$2.28 million to CAN$15.21 million vs. a cost to produce the map of CAN$1.86 million.

Australian Studies

The most recent studies in Australia have typically shown much stronger results than those from a decade ago. ACIL Allen Consulting's 2013 report examined time required for field survey for a photogrammetric survey and for land survey in Australia.[33] Use of CORS instead of survey control marks reduced time required by 75% according to a 2007 study. The study determined that productivity improvements of 50% are possible in engineering surveys augmented with CORS for infrastructure, such as power lines and pipelines in remote areas in 2012. This was based on allowing for improved technologies since a 2007 estimate of 30%-50%. Road assessment over long distances in remote areas required 25% less time in the field and 50% less time in the office. A survey for a large rural boundary adjustment using GNSS saved about 66% in number of meters surveyed per day. Further improvements are likely to have occurred in the five years since the study was conducted.

ACIL Allen Consulting's 2013 study of precise positioning services in the surveying and land management sector in Australia found that: "Productivity improvements are significant in surveying and land management ranging from 20 per cent and 40 per cent in 2012 with a further 20 per cent by 2020. In addition, augmented reality has significant potential to improve the quality of planning and design of land and infrastructure developments through its potential as a 3 dimensional imagery that supports community consultation on design and planning, consultation between surveyor, engineer and architect and design decision making. This has not been included in the productivity assessments."[34]

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[31] The economy-wide effects were based on inter-industry (multiplier) and international relationships estimated from productivity data for sectors in a Computable General Equilibrium (CGE) model.

32 R. Bernknopf, *et. al.*, *Analysis of Improved Government Geological Map Information for Mineral Exploration: Incorporating Efficiency, Productivity, effectiveness, and Risk Considerations*, U.S. Geological Survey Professional Paper 1721, 2007 http://pubs.usgs.gov/pp/pp1721/pp1721.pdf

33 ACIL Allen Consulting, *The Value of Augmented GNSS in Australia*, Prepared for the Australian Department of Industry, Innovation, Climate Change, Research and Tertiary Education, June 2013 http://www.acilallen.com.au/cms_files/ACILAllen_AugmentedGNSS.pdf

[34] ACIL Allen Consulting, *Precise Positioning Services in the Surveying and Land Management Sector*, June 2013, pp.11-12 http://www.ignss.org/LinkClick.aspx?fileticket=8%2FOX44UyLhk%3D&tabid=56

The Allen Consulting Group examined the benefits from establishment of a national CORS system in Australia for mining, agriculture and construction through 2030 in a study in 2008. Benefits were based on increased market penetration of practices producing efficiency gains and interaction effects throughout the economy. Over 30% of the present value of future benefits in agriculture, mining and construction, discounted at a 7% rate, were attributed to development of a proposed standardized network.[35]

In contrast, in a 2008 study, Allen Consulting Group estimated that in land surveys for government asset management in Australia, precision methods produced cost savings of 5%-10% and reduced aggregate capital expenditures by 5%-10%.[36] It also estimated productivity gains from earthmoving machine guidance in Australia of 1.3%-2.6%. In 2008. ACIL Tasman estimated in 2008 that improved productivity from spatial information technologies in construction in Australia of 1%, with an adoption rate of 2.5%-5%.[37]

Studies from Australia reported by Higgins indicated that in fire-fighting, the time for mapping and reporting fire fronts has been reduced from 6-7 hours to 1-2 hours with the use of GPS. Time for photogrammetric surveys in regional areas had been reduced from four months to one week.[38]

Other Studies

The International Federation of Surveyors (FIG) issued a report in 2010 in which costs and useful lives of equipment were taken into account along with labor costs. Costs were reduced by nearly half by the use of geodetic surveying and more than half with both geodetic surveying and CORS.[39]

Konecny examined the cost of aerial photography restitution in a 2008 study. He found that: "…standard orthophotography is by a factor of 6 cheaper than line mapping."[40]

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[35] Allen Consulting Group, *Economic Benefits of High Resolution Positioning Services*¸ Final Report, November 2008 http://www.crcsi.com.au/pages/publications.aspx

[36] Allen Consulting Group, *Economic Benefits of High Resolution Positioning Services*¸ Final Report, November 2008 http://www.crcsi.com.au/pages/publications.aspx

[37] ACIL Tasman, *The Value of Spatial Information*, prepared for the Cooperative Research Centre for Spatial Information and ANZLIC – The Spatial Information Council, March 2008, p.69 https://www.crcsi.com.au/assets/Resources/7d60411d-0ab9-45be-8d48-ef8dab5abd4a.pdf

[38] Matt Higgins, "Queensland Australia, the Smart Choice for GNSS," slides, Queensland Government, n.d. http://www.nrw.qld.gov.au/gnss/events/pdf/systems_matthiggins.pdf The information was downloaded several years ago and its date was not provided.

[39] International Federation of Surveyors (FIG), *Cost Effective GNSS Positioning Techniques*, FIG Commission Publication 49, FIG Commission 5, 2010 http://www.fig.net/pub/figpub/pub49/figpub49.pdf Read from graphs that showed how total costs would vary with labor costs in each case.

[40] Gottfried Konecny, "Economic Considerations for Photogrammetric Mapping," International Archives of the Photogrammetry, Remote Sensing and Spatial Info Sciences, Vol. XXXVII, Part B6A, Bejing 2008, p.209 http://www.isprs.org/proceedings/XXXVII/congress/6a_pdf/6_WG-VI-6/04.pdf

Preliminary Estimates of the Value of the Regional Geodetic Advisor Program

Estimates of benefits of RGAs are made in two parts: 1) training and assistance to clients, and 2) the value of OPUS Projects training which is one of the services RGAs provide in addition to services for their regions.

Illustrative Order of Magnitude of Value of RAP Training and Assistance to Clients

An order of magnitude indication of the value of assistance and training provided by Regional Geodetic Advisors is derived based on benefits of modern geodetic methods over traditional techniques in terms of productivity improvements and cost savings.[41] A small portion of those benefits is used to illustrate the potential magnitude of benefits of RAP activities.

The benefit estimates are made by:

1. Beginning with the numbers of professionals in six occupations potentially using NGS services. Services of survey technicians were incorporated in the estimate for surveyors by inclusion in overhead. For engineering, only civil engineers licensed in surveying as well as engineering were included and they were assumed to be doing surveying work only 20% as often as surveyors. Half of geographers were included assuming some of their work benefits less often from modern geodetic methods

2. Assuming a range of average cost in each occupation, including associated staff and overheads, building on examination of annual earnings

3. Multiplying the number of professionals in each occupation by average cost to derive a range for total cost

4. Assuming modern geodetic techniques reduce costs (or increase productivity) over traditional methods, on average, by 45%-55%. This is based on a review of studies in the previous section. The main calculation assumes the same percentages for each occupation. The percentages are supported by evidence for occupations accounting for most of the activity. An alternative estimate also is made.

5. Calculating what the cost would have been without modern methods based on the percentages of improvements in cost

[41] The savings from avoided cost can be used either to increase output, in which case they are counted as productivity increases, or to reduce costs.

6. Multiplying the percentages of savings from modern methods by the cost without modern methods to obtain a range of estimates of cost saving for each profession

7. Assuming benefits from RGA activities of 0.1% of costs savings from use of modern geodetic methods. The same percentage was used for each occupation. 0.1% can be arrived at with many combinations of its components, for example, with 4% of professionals experiencing increases in productivity of 50% for 5% of their activities

Benefits are computed based on 2016 occupation data which is the latest available. Illustrative average costs in each occupation are for 2018, with the resulting benefit estimates for 2018.

As of the time of this writing, two Regional Geodetic Advisor positions are vacant, some program personnel are relatively new in their roles and the number of Geodetic Partners is growing. The benefit estimates are scaled to full program capacity.

The estimates of benefits of RGA activities for their clients are shown in Table 18, with the range representing 45% and 55% savings.[42] Only the total of the occupations should be relied upon. The details of the calculations are shown in Table 19.

The estimates do not include services such as OPUS training or beta testing new products for NGS. The value of OPUS training is estimated separately.

Table 18. Illustrative Estimates of Value of Benefits of the NGS Regional Geodetic Advisors to Their Clients, 2018
(millions of dollars)

	Number in Occupation	Benefit Estimates
Surveyors (including services of survey technicians)	43,340	6.4-11.7
Civil engineers licensed for surveying (20% of those licensed)	1,177	0.1-0.2
Cartographers and photogrammetrists	12,100	1.2-2.1
Geoscientists except hydrologists and geographers	30,420	4.5-7.4
Hydrologists	6,300	0.9-1.5
Geographers (half)	685	0.1-0.1
Total	**94,022**	**13.2-23.0**

An alternative estimate explores the implications of reducing the savings for geoscientists except hydrologists and geographers from use of modern geodetic methods from 45%-55% to 30%-40%. This is based on the assumption that the 20.7% of geoscientists except hydrologists and geographers who work in oil and gas extraction industry and others in consulting firms that support the industry rely heavily on

[42] The number of civil engineers included is 20% of the number licensed for surveying on the assumption that those who are dual licensed do surveying less often that licensed surveyors.

other technologies, so less of the gains can be attributed to assistance with geospatial methods from NGS. In this alternative case the benefit for geoscientists except hydrologists and geographers is $2.3-$4.1 million and the total benefit is $11.0-$19.6 million. The alternative estimate is not relied on because it is possible that geospatial methods significantly increase the value of other technologies used in oil and gas extraction and other high technology industries, and that more sophisticated geoscientists in industry, rather than needing less assistance, may be better able to benefit from assistance from NGS.

Table 19. Regional Geodetic Advisor Benefit Estimation by Occupation , 2018

GROUP:	A		B		C		D		E		F	
CASE:	1	2	1	2	1	2	1	2	1	2	1	2
	Surveyors (including services of surveying technicians)	Surveyors (includingservices of surveying technicians)	Civil engineers licensed for surveying	Civil engineers licensed for surveying	Cartographers and photogrammetrists	Cartographers and photogrammetrists	Geoscientists, except hydrologists and geographers	Geoscientists, except hydrologists and geographers	Hydrologists	Hydrologists	Geographers (half)	Geographers (half)
1. Number potentially using NGS services	43,340	43,340	1,177	1,177	12,100	12,100	30,420	30,420	6,300	6,300	685	685
2. Average cost for a user in a profession, including associated staff and overheads ($)	180,000	220,000	150,000	170,000	120,000	140,000	180,000	200,000	170,000	190,000	140,000	150,000
addendum: average annual full time wage ($)	63,480	63,480	91,790	91,790	67,390	67,390	106,390	106,390	84,290	84,290	76,790	76,790
3. Total cost (C) (1x2/1,000,000) ($ millions)	7,801	9,535	177	200	1,452	1,694	5,476	6,084	1,071	1,197	96	103
4. Proportion (P) by which modern surveying and related techniques increase productivity or reduce costs, on average, over traditional methods	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55	0.45	0.55
5. What the cost (H) would have been without modern methods H=C/(1-P) ($)	14,184	21,188	321	445	2,640	3,764	9,956	13,520	1,947	2,660	174	228
6. Cost saving from modern methods (4x5) ($ millions)	6,383	11,654	144	245	1,188	2,070	4,480	7,436	876	1,463	78	126
7.Proportion of professionals benefitting from RGA activities times the propotion of their work which benefits times the proportion by which their productivity rises for those activities	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
8. Benefits of RGA services (6x7) ($ millions)	**6.4**	**11.7**	**0.1**	**0.2**	**1.2**	**2.1**	**4.5**	**7.4**	**0.9**	**1.5**	**0.1**	**0.1**

Preliminary Estimate of the Value of OPUS Projects Training

RGAs provide OPUS Projects training for NGS. This is one of their activities in addition to their regional responsibilities. A measure of benefits of OPUS Projects training provides a partial indication of the value of these additional services. (The value of training and assistance in OPUS static and OPUS rapid static is included in the previous estimates of benefits of RGA activities.)

The estimate of the value of OPUS Projects training in 2018 is obtained by:

> Multiplying A) the number trained by RGAs in 2016 by B) the percent of those trained who are expected to use OPUS Projects in an average year, to determine C) the number of those trained in 2016 who use OPUS Projects in a year
>
> Multiplying C) the number of users trained in 2016 who use OPUS Projects in a year by D) the number of times OPUS Projects is used by an average user in a year, to determine E) the number of instances of use in an average year by those trained in 2016
>
> Multiplying E) the number of instances of use by F) the average number of marks in each project, to determine G) the total number of marks submitted by those trained in a year
>
> Multiplying G) the number of marks submitted by those trained in a year by H) the average value of a resolved mark in 2018, to determine I) the value of OPUS Projects training in the year

A) 373 people received OPUS Projects training from by RGAs in FY2017, either in classrooms or in Webinars.

B) 70%

C) 261.1

D) 1.43

E) 373.4

F) 3.0

G) 1,120.1

H) $1,000-$1,100 (see below)

I) $1.1-$1.2 million

The average avoided cost of an OPUS Share use is taken in the present study to be the January 1, 2015 Canadian cost of one use of CSRS-PPP of C$1000 based on Klatt,[43] as discussed in the section reviewing studies of geospatial benefits. This was converted to U.S. dollars and updated to calendar year 2018. Updating was done with the approximate 8.5 % increase in average weekly earnings in the 3½ years between January 1, 2005 and mid-2018. This places the value per OPUS Share use in year 2018 U.S. dollars at $846. The value of an OPUS Projects mark is increased to $1,000-$1,100 to reflect the greater value of OPUS Projects data than OPUS share data.

At a value of $1,000-$1,100 per resolved mark in 2018, the value of OPUS Projects marks created in 2018 by those trained by RGAs in 2016 is $1.2-$1.2 million.

Combined Preliminary Estimate of Direct Benefit of RAP

If RGA services to constituents accounted for as little as 0.1% of the savings from the use of modern geospatial methods over traditional methods, they would be worth $13.3-$23.0 million. Adding $1.1-$1.2 million for the value of OPUS training, the combined value of RGA activities in 2018 would be $14.3-$24.2 million (Table 21).

The estimates refer to benefits that would have been obtained if the program had been operating at full capacity which it achieved in calendar year 2018. Effects of the RGA program on the cost and success of scientific and environmental activities are not included. Benefits could be a lot higher in the future when many more people need help in adjusting to changing reference frames and geopotential datum.

> If RGA services to constituents accounted for as little as 0.1% of the savings from the use of modern geospatial methods over traditional methods, they would be worth $13.3-$23.0 million. Adding $1.1-$1.2 million for the value of OPUS training, the combined value of RGA activities in 2018 would be $14.3-$24.2 million …. Benefits could be a lot higher in the future when many more people need help in adjusting to changing reference frames and geopotential datum.

The estimates do not include benefits to users outside the United States. Klatt estimated that annual benefits of use outside of Canada were as large as benefits for use inside Canada: C$42.3 million for use outside Canada on January 1, 2015 vs. C$44.0 million for use inside Canada on July 1, 2014-June 30, 2015.[44]

Multiplier Effects

In addition to direct economic benefits there are indirect benefits from increased activity in supporting industries and benefits induced in the rest of the economy. While some studies have used large

[43] Calvin Klatt," Estimating Benefits to Canada and the World: The Canadian Spatial Reference System, Precise Point Positioning Service," *Geomatica*, September 6, 2017 http://pubs.cig-acsg.ca/doi/abs/10.5623/cig2017-104

[44] Calvin Klatt," Estimating Benefits to Canada and the World: The Canadian Spatial Reference System, Precise Point Positioning Service," *Geomatica*, September 6, 2017 http://pubs.cig-acsg.ca/doi/abs/10.5623/cig2017-104

multipliers, which makes benefits look more attractive, the intent in this study is to be conservative in the absence of information that is specific to the RGA program or activities of NGS.

Some studies have found multipliers to be around two, which means that benefits to supplying industries plus benefits induced in the rest of the economy are as large as the direct benefits of the program.[45] This study uses a conservative multiplier of 1.3-1.6 to illustrate the possible implications of including broader effects on the value of benefits.

With an output multiplier of 1.3-1.6, the expanded combined value of services of RGAs to their constituents and to NGS in 2018 is on the order of magnitude of $18.6-$38.7 million.

With an output multiplier of 1.3-1.6, the expanded combined value of services of RGAs to their constituents and to NGS in 2018 is on the order of magnitude of $18.6-$38.7 million. The full set of order of magnitude estimates are shown in Table 20.

Table 20. Illustrative Estimates of Total Benefits of the NGS Regional Geodetic Advisors Program, 2018
(millions)

	Direct	**Expanded (multiplier 1.3-1.6)**
RGA services to constituents	$13.2-$23.0	*$17.2-$36.8*
RGA OPUS training for NGS	$1.1-$1.2	*$1.4-$1.9*
Total	**$14.3-$24.2**	***$18.6-$38.7***

Note: The estimates refer to benefits if the program had been operating at full capacity as it is in calendar year 2018.

Present Value of Future Benefits

Next, illustrative scenarios for order of magnitude of future benefits of the Regional Geodetic Advisor Program are considered. Benefits are calculated for each of the ten years 2018-2027 and present discounted values of future benefits are calculated.

[45] The αlphaβeta 2017 study of the economic impact of geospatial services found that globally there are about as many jobs indirectly linked to geospatial service (using a broad definition that covers applications including satellite services) as directly linked jobs. A multiplier implies causation while "linkage" loosely includes some degree of geospatial content or reliance on geospatial services. αlphaβeta, *The Economic Impact of Geospatial Services: How Consumers, Businesses and Society Benefit from Location-Based Services*, September, 2017, p.52 http://www.alphabeta.com/wp-content/uploads/2017/09/GeoSpatial-Report_Sept-2017.pdf

One scenario assumes 2% growth in benefits per year to reflect growth of real GDP. The alternative scenario assumes that benefits increase by 4% per year as a result both of improvements in technology which make new methods more valuable in relation to older methods and the growing value of RGA services with the introduction of new terrestrial reference frames and geopotential datum. Benefits are not assumed to grow even faster than 4% because of the historically slow pace at which new reference frames and datum have been adopted and the possibility that RGAs will have to spend more time with each client because of the added complexity with more reference frames and datum.

The value of benefits is discounted to the present to reflect the greater value of immediate benefits than those that are deferred. The U.S. Office of Management and Budget has issued guidance to use a discount rate of 7% above inflation for primary estimates by government agencies and the rate is frequently used by economists.[46] Results of a 4% discount rate are also computed since 4% may be closer to interest rates on Treasury bonds over the period. Results of the calculations are shown in Table 21.

The 10-year present discounted value of RGA services to clients with the multiplier (expanded) effects included ranges from $130.8 million (with 2% growth and a 7% discount rate) to $372.1 million (with a 4% growth and a 4% discount rate.)[47] Without the multiplier (expanded) effects the range would be $100.4-$222.7 million.

The expanded present discounted value of OPUS training ranges from $10.6-$18.3 million with expanded benefits and from $8.4-$11.5 million without expanded benefits.

The 10-year expanded present discounted value of combined benefits ranges from $141.5-$372.1 million. Without expanded benefits, combined benefits range from $108.8-$232.7 million.

The preferred illustrative estimate of ten-year discounted benefits of the of the Regional Geodetic Advisor Program is for combined benefits with a 4% growth rate and a 7% discount rate. This is a more realistic growth rate of benefits and a more conservative discount rate. On this basis a preliminary present value of combined expanded benefits is $153.59-$319.3 million and without the multiplier it is $118.0-$199.7 million.

[46] U.S. Office of Management and Budget, “Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs,” Circular A-94, October 29, 1992, p.9 https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf

[47] The discounted values in the Excel NPV formula treats the benefits as occurring at the end of each year rather than evenly throughout the year.

Table 21. Present Values of Benefits of the NGS Regional Geodetic Advisors Program
(millions of year 2018 dollars)

	Direct Benefits				Expanded Benefits			
Discount Rate:	4%		7%		4%		7%	
	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range
2% Growth Rate								
Services to Clients	116.5	203.0	100.4	174.9	151.8	324.7	130.8	279.9
OPUS Training for NGS	9.7	10.6	8.4	9.1	12.4	16.8	10.6	14.5
Combined Benefits	126.2	213.6	108.8	184.1	164.1	341.5	141.5	294.4
4% Growth Rate								
Services to Clients	126.9	221.2	108.9	189.8	165.4	353.8	141.9	303.6
OPUS Training for NGS	10.6	11.5	9.1	9.9	13.5	18.3	11.6	15.7
Combined Benefits	137.5	232.7	118.0	199.7	178.8	372.1	153.5	319.3

Preliminary Estimate of the Program's Impact on Jobs

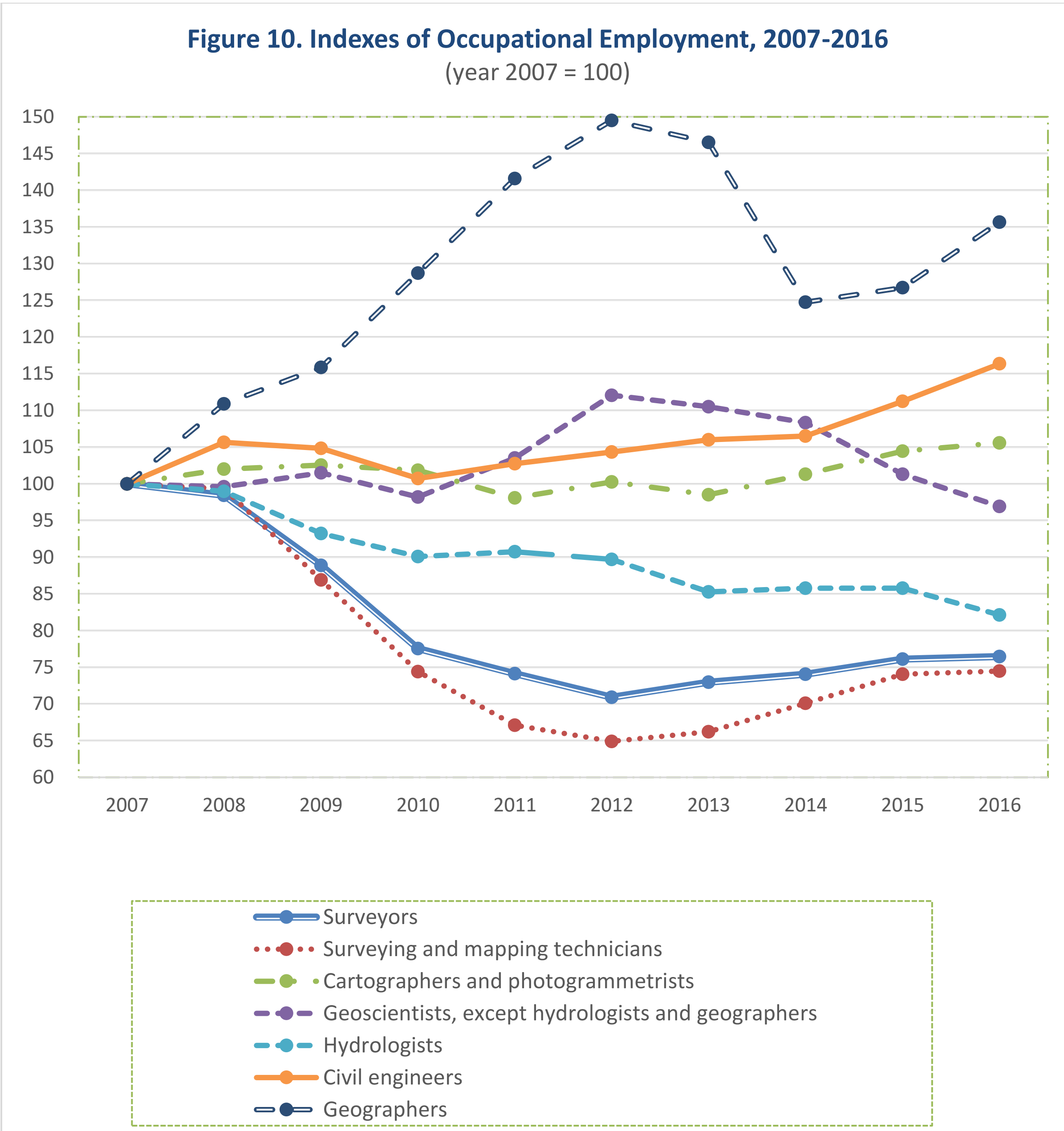
While cost savings from the use of modern geospatial methods can reduce the number of jobs, there are positive influences as well. For example, a decline in the cost of geospatial services can lead to a greater amount of activity both directly and indirectly. Lower cost reduces the cost of activities that rely on geospatial services, potentially leading to more of them. Modern geodetic methods make measurement more accurate and reliable which in turn can enhance the products for which they are used or enable new products, with the expansion of products creating additional demand for geospatial services.

Modern geodetic methods also can affect the numbers of jobs through their impact on skill mix. If the same work can be done by fewer people with greater skills, there can be a reduction in jobs but higher average incomes. In contrast, the number of jobs and average incomes can fall if activities become routine so that more can be done by fewer people with lesser skills.

The greatest influence has been the economic cycle, with several geospatial occupations showing sharp declines in employment after 2007 because of declines in construction and investment in plant and equipment. Employment patterns are shown in Figure 9 in which each occupation is an index with its value in 2007 equal to 100. Employment has not fully bounced back from 2009 levels and in some occupations it has continued to decline. At the same time, there were small increases in the higher skill category of cartographers and photogrammetrists. Significant increases have occurred in the number of geographers during 2014-2016, but these are small relative to the declines in other occupational categories.

The open question is the effect on the large category of civil engineers. Their numbers have been growing but there are no indications in the information obtained thus far that overall, they are doing an increasing amount of surveying and related types of work.

At this time, it is necessary to conclude that, abstracting from cyclical influences, increasing use of modern geospatial methods has not had a noticeable positive impact on the numbers of jobs in associated fields from 2007 through 2016 and may even have had a negative effect. Net impacts may have been positive in the stronger economy since 2016, so the impact for the full 2007- 2018 period is taken to be flat.



Source: https://www.bls.gov/oes/tables.htm

Potential Strategic Opportunities

During the analysis several approaches have been noted which may provide opportunities for improving the results of the program.

Leveraging the RGA Program and Increasing User Knowledge

With so many thousands of users of NGS services and so few people in NGS and RAP, the Regional Geodetic Advisor Program must leverage the program as fully as possible. NGS has many potential ways of leveraging the RAP in approaches currently in use and others noted in italics, so that it reaches more clients or produces greater impacts. The program can take advantage of the whole range of opportunities so users can fully benefit from its current capabilities and advances in data and tools.

- Use of the Internet, social media and email lists
- Speaking to large groups
    - Trade and NGS national and state conferences, NGS Testing and Training Center, state and local government workshops
        - When someone asks a good question at a meeting, the RGA can offer to hold a group meeting with people in their organization at their location
- Field activities of RGAs may potentially have high payoffs. Examples include:
    - Working with state and local partners helping RTNs networks set up CORS installations and helping with calibration baselines
    - Helping with linking adjacent surveying projects whether of the same type or not in order to avoid having to determine the precise location for each project separately
    - Serving as project managers for a large project when requested
    - Helping if there is a new procedure such as river crossing, providing on the ground training and updated guidelines
    - Working with USGS, USACE and USBR on other questions
- *Training people who train others or determine training for their staff ("training the trainers")*
- Assistance in bluebooking benchmarks which provide reference points for use by others
- *Giving extra attention to training in situations with insufficient supplies of personnel or skills that can prevent activities from moving forward*

- *Emphasizing training or assistance to projects that potentially have large multiplier effects such as infrastructure construction projects where the additional knowledge or information could reduce project delays and affect others along the value chain.*
- Promoting licensing requirements for geodesists
- *Training and assistance, the results of which results are embedded in a form that can be used by many others without the presence of an RGA. Examples include forms such as maps, software, databases, curriculums and manuals.*[48]
  - Advisors have been asked to consult on updates to state manuals defining the state's surveying and/or engineering standards for sections relating to ties to the NSRS
  - RGAs participate in in state committees that develop licensing requirements, providing advice on curriculum and means of learning.
  - NGS has encouraged state licensing for geodesists. RGAs can provide assistance in developing the standards and determining means by which licensees can attain them.

Bridging to Facility with Standards and Requirements

It has been suggested that most of the RGA talks at professional and trade association meetings cover "Geodesy 101." Of course, this is a simplification since the talks also cover new datums and other NGS services, speakers take questions on many subjects and referrals are made to more advanced materials on the NGS Website. But there is a concern that a growing number of users of the National Spatial Reference System are "button pushers" who don't sufficiently understand the geodesy behind their calculations, which makes them vulnerable to mistakes. Therefore, the question is how to encourage and provide support for users to advance their knowledge beyond the "Geodesy 101" level. Some of this must involve greater formal education but there is much NGS can do.

> Common themes in recommendations from NGS partner agencies regarding outreach for new terrestrial reference frames and geopotential datums include: "continuing NGS geospatial summits and monthly training webinars;… educating GIS and other professionals who work with geospatial data but have limited geodetic knowledge; and collaborating with NSPS to [update legislation that references datums]." [49]

Activities which contribute include:

[48] An example of a manual is https://www.codot.gov/business/manuals/survey

[49] U.S. National Oceanic and Atmospheric Administration, National Geodetic Survey, *2017 Geospatial Summit: Modernizing the National Spatial Reference System*, NOAA Special Publication NOS NGS 12, Silver Spring, April 24-25, 2017, pp.17-18 https://www.ngs.noaa.gov/library/pdfs/SP_NOS_NGS_12.pdf

- Talks and outreach at state society meetings and state conventions
- Training people who train others and/or make decisions about training of others
- Promoting licensing requirements for geodesists
- Participating in or supporting state committees determining licensing requirements
- Working with colleges and universities to encourage appropriate curriculum

Modifying the Emphasis among Using Fields and Sectors

It was noted that while RGAs give a disproportionate amount of attention to government; 10.9% of surveyors are in government compared and 37.5% are in engineering services, not all of whom are serving local governments. 5.4% are in sectors directly related to construction, and 42.0% are widely scattered among other industries. At the same time, a growing number of users of the NSRS are in occupations other than surveying and geodesy. This suggests that the RAP and NGS consider whether it is possible to obtain greater benefits from assistance by more fully addressing needs of a broader range of sectors and fields.

Developing a strategy for doing so requires understanding of the needs of each sector and type of user, how they are currently being met and how they might be met. If some sectors are not sufficiently served and can benefit from modified or additional services of RAP, RAP can modify its efforts.

Newsletter with Regional Variations and Other Forms of Communications

NGS could consider tailored regional versions of notification emails and/or converting the notifications to an email newsletter with regional versions. The Material could include information of interest to specific industry sectors. Regional Geodetic Advisors could contribute content of regional interest.

Other possibilities for communication that might be considered include encouraging inclusion of speakers notes in presentations on the NGS Website, providing recordings of some of the talks, and developing YouTube videos with guides to NGS and RGA services and how-to demonstrations.

Possibilities for More Extensive Analysis

1. **The Future of the NGS and RGA Service Needs and Responses:** The types of users of the National Spatial Reference System has been increasing and a major change in reference frames and geopotential datum is being implemented by NGS. As a result, the NGS and the Regional Geodetic Advisor Program will face a future in which they will have to serve more constituents with an increasing variety and complexity of backgrounds and needs. It would be worthwhile to anticipate and explicitly project scenarios for changes in clientele and NGS product needs and consider ways NGS and the Regional Geodetic Advisor Program can contribute to meeting those needs.

   It would be worthwhile to anticipate and explicitly project scenarios for changes in clientele and NGS product needs and consider ways the Regional NGS and the Geodetic Advisor Program can contribute to meeting those needs.

2. **Estimating Benefits of RGA Field Activities**: *A* promising subject for further benefit estimation is the field activities of RGAs, many of which may have high payoffs. In this context field activities refers to special assignments and one-time efforts beyond usual activities. Even a partial estimate including the most important of these could give an additional measure of the value of the RAP and be useful in allocating effort. It may be possible to include some safety-of-life and environmental benefits in such case studies. Field activities of RGAs include working with state and local partners, helping RTN networks set up CORS stations and helping with calibration baselines, serving as project managers for large projects, helping if there is a new procedure such as river crossing, and providing on-the-ground training and updated guidelines for USGS, USACE, USBR and other government organizations.[50]

   A promising subject for further benefit estimation is the field activities of RGAs, many of which may have high payoffs.

3. **Examining Ways of Leveraging Efforts of NGS and RAP**: It would be useful to systematically examine current and potential methods of leveraging the program. A study could examine the extent to which methods are currently being used, possibilities for expanding their use and possibilities for use of additional methods. This would involve detailed consideration of methods, where and how they are applied, types of situations in which they could be applied, actions needed to support their application and potential improvements in program performance with their use

   It would be useful to systematically examine current and potential methods of leveraging the program.

[50] It was hoped that at a pilot level it would be possible to identify everyday clients of RGAs who could provide access to data on individual (non-field activity) cases in which RGAs contributed so impacts of RGAs on projects could be estimated. It turned out that this would require far more interviews than was possible in a scoping study and sufficient information might not be obtained even in a larger study. Even if sufficient information could be obtained and estimates developed, the analysis would cover only a small portion of RGA activities and the results might not be representative of even those types of activities. In view of these considerations and the development "ball park" indications of the program's benefits in this scoping study, such an effort is not recommended.

Appendices

Appendix A. Definitions of Surveying and Mapping Industries in the 2017 North American Industrial Classification System (NAICS)

“541370 Surveying and Mapping (except Geophysical) Services

This industry comprises establishments primarily engaged in performing surveying and mapping services of the surface of the earth, including the sea floor. These services may include surveying and mapping of areas above or below the surface of the earth, such as the creation of view easements or segregating rights in parcels of land by creating underground utility easements. Illustrative Examples: Cadastral surveying services Mapping (except geophysical) services Cartographic surveying services Topographic surveying services Geodetic surveying services.

> Cross-References. Publishing atlases and maps, except for exclusive Internet publishing--are classified in Industry 511130, Book Publishers; and Publishing atlases and maps exclusively on the Internet--are classified in Industry 519130, Internet Publishing and Broadcasting and Web Search Portals.

541360 Geophysical Surveying and Mapping Services

This industry comprises establishments primarily engaged in gathering, interpreting, and mapping geophysical data. Establishments in this industry often specialize in locating and measuring the extent of subsurface resources, such as oil, gas, and minerals, but they may also conduct surveys for engineering purposes. Establishments in this industry use a variety of surveying techniques depending on the purpose of the survey, including magnetic surveys, gravity surveys, seismic surveys, or electrical and electromagnetic surveys.

> Cross-References. Establishments primarily engaged in taking core samples, drilling test wells, or other mine development activities (except geophysical surveying and mapping) on a contract basis for others are classified in Industry 21311, Support Activities for Mining. 54137 Surveying and Mapping.”

Source: Executive Office of the President, Office of Management and Budget, *North American Industrial Classification System, United States, 2017*
https://www.census.gov/eos/www/naics/2017NAICS/2017_NAICS_Manual.pdf

Appendix B. 2018 Standard Occupational Classification

“17-1020 Surveyors, Cartographers, and Photogrammetrists
17-1022 Surveyors

Research, study, and prepare maps and other spatial data in digital or graphic form for one or more purposes, such as legal, social, political, educational, and design purposes. May work with Geographic Information Systems (GIS). May design and evaluate algorithms, data structures, and user interfaces for GIS and mapping systems. May collect, analyze, and interpret geographic information provided by geodetic surveys, aerial photographs, and satellite data.

17-1021 Cartographers and Photogrammetrists

Research, study, and prepare maps and other spatial data in digital or graphic form for one or more purposes, such as legal, social, political, educational, and design purposes. May work with Geographic Information Systems (GIS). May design and evaluate algorithms, data structures, and user interfaces for GIS and mapping systems. May collect, analyze, and interpret geographic information provided by geodetic surveys, aerial photographs, and satellite data.

17-3031 Surveying and Mapping Technicians

Perform surveying and mapping duties, usually under the direction of an engineer, surveyor, cartographer, or photogrammetrist, to obtain data used for construction, mapmaking, boundary location, mining, or other purposes. May calculate mapmaking information and create maps from source data, such as surveying notes, aerial photography, satellite data, or other maps to show topographical features, political boundaries, and other features. May verify accuracy and completeness of maps. Excludes “Cartographers and Photogrammetrists” (17-1021), “Surveyors" (17-1022), and “Geoscientists, Except Hydrologists and Geographers” (19-2042).

19-2042 Geoscientists, Except Hydrologists and Geographers

Study the composition, structure, and other physical aspects of the Earth. May use geological, physics, and mathematics knowledge in exploration for oil, gas, minerals, or underground water; or in waste disposal, land reclamation, or other environmental problems. May study the Earth’s internal composition, atmospheres, and oceans, and its magnetic, electrical, and gravitational forces. Includes mineralogists, paleontologists, stratigraphers, geodesists, and seismologists.

19-2043 Hydrologists

Research the distribution, circulation, and physical properties of underground and surface waters; and study the form and intensity of precipitation and its rate of infiltration into the soil, movement through the earth, and return to the ocean and atmosphere.

19-3092 Geographers

Study the nature and use of areas of the Earth’s surface, relating and interpreting interactions of physical and cultural phenomena. Conduct research on physical aspects of a region, including land forms, climates, soils, plants, and animals, and conduct research on the spatial implications of human activities within a given area, including social characteristics, economic activities, and political organization, as well as researching interdependence between regions at scales ranging from local to global.

17-2051 Civil Engineers

Perform engineering duties in planning, designing, and overseeing construction and maintenance of building structures and facilities, such as roads, railroads, airports, bridges, harbors, channels, dams, irrigation projects, pipelines, power plants, and water and sewage systems. Includes architectural, structural, traffic, and geotechnical engineers. Excludes “Hydrologists” (19-2043).

19-1032 Foresters

Manage public and private forested lands for economic, recreational, and conservation purposes. May inventory the type, amount, and location of standing timber, appraise the timber’s worth, negotiate the purchase, and draw up contracts for procurement. May determine how to conserve wildlife habitats, creek beds, water quality, and soil stability, and how best to comply with environmental regulations. May devise plans for planting and growing new trees, monitor trees for healthy growth, and determine optimal harvesting schedules.

17-2151 Mining and Geological Engineers, Including Mining Safety Engineers

Conduct subsurface surveys to identify the characteristics of potential land or mining development sites. May specify the ground support systems, processes, and equipment for safe, economical, and environmentally sound extraction or underground construction activities. May inspect areas for unsafe geological conditions, equipment, and working conditions. May design, implement, and coordinate mine safety programs. Excludes “Petroleum Engineers” (17-2171).

17-2171 Petroleum Engineers

Devise methods to improve oil and gas extraction and production and determine the need for new or modified tool designs. Oversee drilling and offer technical advice.

19-4043 Geological Technicians, Except Hydrologic Technicians

Assist scientists or engineers in the use of electronic, sonic, or nuclear measuring instruments in laboratory, exploration, and production activities to obtain data indicating resources such as metallic ore, minerals, gas, coal, or petroleum. Analyze mud and drill cuttings. Chart pressure, temperature, and other characteristics of wells or bore holes.

19-4044 Hydrologic Technicians

Collect and organize data concerning the distribution and circulation of ground and surface water, and data on its physical, chemical, and biological properties. Measure and report on flow rates and ground water levels, maintain field equipment, collect water samples, install and collect sampling equipment, and process samples for shipment to testing laboratories. May collect data on behalf of hydrologists, engineers, developers, government agencies, or agriculture. Excludes “Hydrologists” (19-2043).”

Source: https://www.bls.gov/soc/2018/home.htm

Appendix C. A Test of Changes in the Quantity or Value of Skill Based on Earnings Distributions

If either increases in skill or increases in the compensation received by persons with above average skill levels in their profession have accompanied recent geoscience technological changes, it ought to be possible to observe an increased concentration of income among those with the highest income levels. In fact, the extent of that concentration can provide a way to measure the value of skill regardless of whether the increased value comes from a change in the amount of skill or the compensation a given amount of skill receives. To test for increasing income concentration, the ratio of mean to median hourly wages was examined for each of the categories that were included in the occupational analysis.

A rise in the ratio of mean to median hourly wages was found for the occupation “geoscientists except hydrologists and geographers.” The ratio rose from an average of 1.109 in 2005-2007 to 1.185 in 2016 (Table C-1). However, no such increase was found for the other occupational categories. This suggests that at least so far, extraordinary increases in skill or the compensation it receives have been confined to geodesy – which has been on the forefront of the geoscience technological revolution.

Table C1. Ratios of Average Hourly Earnings of Surveyors to those of Surveying and Mapping Technicians, 2005-2016

Year	Ratio of Mean Average Hourly Earnings of Surveyors to Surveying and Mapping Technicians	Ratio of Median Average Hourly Earnings of Surveyors to Surveying and Mapping Technicians
2005	1.47	1.47
2006	1.49	1.49
2007	1.52	1.53
2008	1.49	1.51
2009	1.45	1.46
2010	1.44	1.45
2011	1.40	1.41
2012	1.39	1.42
2013	1.37	1.39
2014	1.38	1.40
2015	1.41	1.38
2016	1.40	1.40

Source: U.S. Bureau of Labor Statistics, Occupational Outlook Statistics https://www.bls.gov/oes/tables.htm

Appendix D. Scenarios for Present Value Calculations

Table D1. Present Values of Benefits of the NGS Regional Geodetic Advisors Program with a 2% Growth Rate (millions of year 2018 dollars)

Services to Clients								
	Direct				Expanded			
	4%		7%		4%		7%	
	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range
NPV	116.5	203.0	100.4	174.9	151.8	324.7	130.8	279.9
2018	13.2	23.0	13.2	23.0	17.2	36.8	17.2	36.8
2019	13.5	23.5	13.5	23.5	17.5	37.5	17.5	37.5
2020	13.7	23.9	13.7	23.9	17.9	38.3	17.9	38.3
2021	14.0	24.4	14.0	24.4	18.3	39.1	18.3	39.1
2022	14.3	24.9	14.3	24.9	18.6	39.8	18.6	39.8
2023	14.6	25.4	14.6	25.4	19.0	40.6	19.0	40.6
2024	14.9	25.9	14.9	25.9	19.4	41.4	19.4	41.4
2025	15.2	26.4	15.2	26.4	19.8	42.3	19.8	42.3
2026	15.5	26.9	15.5	26.9	20.2	43.1	20.2	43.1
2027	15.8	27.5	15.8	27.5	20.6	44.0	20.6	44.0
OPUS Training for NGS								
	Direct				Expanded			
	4%		7%		4%		7%	
	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range
NPV	9.7	10.6	8.4	9.1	12.4	16.8	10.6	14.5
2018	1.1	1.2	1.1	1.2	1.4	1.9	1.4	1.9
2019	1.1	1.2	1.1	1.2	1.4	1.9	1.4	1.9
2020	1.1	1.2	1.1	1.2	1.5	2.0	1.5	2.0
2021	1.2	1.3	1.2	1.3	1.5	2.0	1.5	2.0
2022	1.2	1.3	1.2	1.3	1.5	2.1	1.5	2.1
2023	1.2	1.3	1.2	1.3	1.5	2.1	1.5	2.1
2024	1.2	1.4	1.2	1.4	1.6	2.1	1.6	2.1
2025	1.3	1.4	1.3	1.4	1.6	2.2	1.6	2.2
2026	1.3	1.4	1.3	1.4	1.6	2.2	1.6	2.2

2027	1.3	1.4	1.3	1.4	1.7	2.3	1.7	2.3
Combined Benefits								
	Direct				Expanded			
	4%		7%		4%		7%	
	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range
NPV	126.2	213.6	108.8	184.1	164.1	341.5	141.5	294.4
2018	14.3	24.2	14.3	24.2	18.6	38.7	18.6	38.7
2019	14.6	24.7	14.6	24.7	19.0	39.5	19.0	39.5
2020	14.9	25.2	14.9	25.2	19.4	40.3	19.4	40.3
2021	15.2	25.7	15.2	25.7	19.7	41.1	19.7	41.1
2022	15.5	26.2	15.5	26.2	20.1	41.9	20.1	41.9
2023	15.8	26.7	15.8	26.7	20.5	42.7	20.5	42.7
2024	16.1	27.3	16.1	27.3	20.9	43.6	20.9	43.6
2025	16.4	27.8	16.4	27.8	21.4	44.5	21.4	44.5
2026	16.8	28.4	16.8	28.4	21.8	45.3	21.8	45.3
2027	17.1	28.9	17.1	28.9	22.2	46.3	22.2	46.3

Table D2. Present Values of Benefits of the NGS Regional Geodetic Advisors Program with a 4% Growth Rate (millions of year 2018 dollars)

Services to Clients								
	Direct				Expanded			
	4%		7%		4%		7%	
	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range
NPV	126.9	221.2	108.9	189.8	165.4	353.8	141.9	303.6
2018	13.2	23.0	13.2	23.0	17.2	36.8	17.2	36.8
2019	13.7	23.9	13.7	23.9	17.9	38.3	17.9	38.3
2020	14.3	24.9	14.3	24.9	18.6	39.8	18.6	39.8
2021	14.8	25.9	14.8	25.9	19.3	41.4	19.3	41.4
2022	15.4	26.9	15.4	26.9	20.1	43.1	20.1	43.1
2023	16.1	28.0	16.1	28.0	20.9	44.8	20.9	44.8
2024	16.7	29.1	16.7	29.1	21.8	46.6	21.8	46.6
2025	17.4	30.3	17.4	30.3	22.6	48.4	22.6	48.4
2026	18.1	31.5	18.1	31.5	23.5	50.4	23.5	50.4
2027	18.8	32.7	18.8	32.7	24.5	52.4	24.5	52.4
OPUS Training for NGS								
	Direct				Expanded			
	4%		7%		4%		7%	
	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range
NPV	10.6	11.5	9.1	9.9	13.5	18.3	11.6	15.7
2018	1.1	1.2	1.1	1.2	1.4	1.9	1.4	1.9
2019	1.1	1.2	1.1	1.2	1.5	2.0	1.5	2.0
2020	1.2	1.3	1.2	1.3	1.5	2.1	1.5	2.1
2021	1.2	1.3	1.2	1.3	1.6	2.1	1.6	2.1
2022	1.3	1.4	1.3	1.4	1.6	2.2	1.6	2.2
2023	1.3	1.5	1.3	1.5	1.7	2.3	1.7	2.3
2024	1.4	1.5	1.4	1.5	1.8	2.4	1.8	2.4
2025	1.4	1.6	1.4	1.6	1.8	2.5	1.8	2.5
2026	1.5	1.6	1.5	1.6	1.9	2.6	1.9	2.6
2027	1.6	1.7	1.6	1.7	2.0	2.7	2.0	2.7
Combined Benefits								
	Direct				Expanded			
	4%		7%		4%		7%	
	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range	bottom of range	top of range
NPV	137.5	232.7	118.0	199.7	178.8	372.1	153.5	319.3
2018	14.3	24.2	14.3	24.2	18.6	38.7	18.6	38.7
2019	14.9	25.2	14.9	25.2	19.3	40.2	19.3	40.2

2020	15.5	26.2	15.5	26.2	20.1	41.9	20.1	41.9
2021	16.1	27.2	16.1	27.2	20.9	43.5	20.9	43.5
2022	16.7	28.3	16.7	28.3	21.8	45.3	21.8	45.3
2023	17.4	29.4	17.4	29.4	22.6	47.1	22.6	47.1
2024	18.1	30.6	18.1	30.6	23.5	49.0	23.5	49.0
2025	18.8	31.8	18.8	31.8	24.5	50.9	24.5	50.9
2026	19.6	33.1	19.6	33.1	25.5	53.0	25.5	53.0
2027	20.4	34.4	20.4	34.4	26.5	55.1	26.5	55.1

Appendix E. Some Interview Questions

Unstructured interviews were held with Regional Geodetic Advisors, State Geodetic Coordinators and others drawing on a long list of possible questions. The unstructured form allowed us to explore matters that arose during the discussions while doubling back to questions that had not yet been addressed. Questions differed according to the category of the person and were varied according to the flow of the discussion. Some examples of questions for RGAs are:

- What do you see as the major needs in your region?
- Who do you see as your main clients?
- How many of your clients' train others or make decisions about training in their organization?
- What communications venues, tools, and approaches do you use to interact with clients?
- How many talks do you give to trade and professional associations, NOAA conferences and other large groups per year?
- What percent of your time do you spend responding to inquiries from the from the NGS Information Center?
- How much interaction with clients do you have at or near your location vs. when traveling?
- What kinds of field work have you done? Describe the projects.
- What do you see as the benefits of your assistance?
- Do you believe your activities significantly increase the productivity or reduce costs for those that you reach?
- What percent of your time do you spend on activities related to your region vs. overall non-advisory NGS-related activities? (OPUS projects training, etc.)
- How do you see your role in relation to the State Geodetic Coordinators?
- What are your views of the Regional Geodetic Advisor Program?
- Can you recommend and provide contact information for clients and their end-users that might be able to provide information on changes that grew out of your assistance?

Some of the same questions and others were asked of State Geodetic Coordinators. Questions for those outside the program included their main activities, views of and interactions with the RAP and previous state programs, roles in training and others to speak to.

Persons Interviewed

Name	Affiliation
Marc Cheves	Editor, American Surveyor
Brett Howe	Director, NGS Geodetic Services Division
Ross Mackay	NGS Geodetic Advisor Branch Chief
Dan Martin	Regional Geodetic Advisor, Northeast
Scott Martin	California Geodetic Coordinator
David Newcomer	former State Geodetic Advisor, FL; trainer for equipment distributor
William Stone	Regional Geodetic Advisor, Southwest
David Zilkoski	former Director, NGS; currently geodetic consultant

Glossary

Abbreviation	Full Name
ASCE	American Society of Civil Engineers
BLM	U.S. Bureau of Land Management
BLS	U.S. Bureau of Labor Statistics
CORS	Continuously Operating Reference Station
FTP	File Transfer Protocol
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPSBM	GPS on Bench Marks program
GRAV-D	Gravity for the Redefinition of the American Vertical Datum
GSD	Geodetic Services Division of NGS
HARN	High Accuracy Research Network
NCEES	National Council of Examiners for Engineering and Surveying
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NSPS	National Society of Professional Surveyors
NSRS	National Spatial Reference System
OPUS	Online Positioning User Service
OPUS-S	Online Positioning User Service-Static
OPUS-RS	Online Positioning User Service-Rapid Static
PPP	Precise Point Positioning
RTK	Real Time Kinematic
RTN	Real Time Network
UESI	Utility Engineering and Surveying Institute of ACE
UFCORS	User-friendly CORS
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VRS	Virtual Reference System

References

ACIL Allen Consulting, *Precise Positioning Services in the Surveying and Land Management Sector*, June 2013 http://www.ignss.org/LinkClick.aspx?fileticket=8%2FOX44UyLhk%3D&tabid=56

ACIL Allen Consulting, *The Value of Augmented GNSS in Australia*, Prepared for the Australian Department of Industry, Innovation, Climate Change, Research and Tertiary Education, June 2013 http://www.acilallen.com.au/cms_files/ACILAllen_AugmentedGNSS.pdf

ACIL Tasman, *The Value of Spatial Information*, prepared for the Cooperative Research Centre for Spatial Information and ANZLIC – The Spatial Information Council, March 2008 https://www.crcsi.com.au/assets/Resources/7d60411d-0ab9-45be-8d48-ef8dab5abd4a.pdf

Allen Consulting Group, *Economic Benefits of High Resolution Positioning Services*¸ Final Report, November 2008 http://www.crcsi.com.au/pages/publications.aspx

αlphaβeta, *The Economic Impact of Geospatial Services: How Consumers, Businesses and Society Benefit from Location-Based Services*, September 2017 http://www.alphabeta.com/wp-content/uploads/2017/09/GeoSpatial-Report_Sept-2017.pdf

Bernknopf, R., *et*. *al*., *Analysis of Improved Government Geological Map Information for Mineral Exploration: Incorporating Efficiency, Productivity, effectiveness, and Risk Considerations*, U.S. Geological Survey Professional Paper 1721, 2007 http://pubs.usgs.gov/pp/pp1721/pp1721.pdf

Burch, Tim, "GPS, Surveyors and Politics – a 2018 Refresher," GPSWorld.com, March 7, 2-18 http://gpsworld.com/gps-surveyors-and-politics-a-2018-refresher/

Dewberry & Davis and Psomas & Associates, *National Height Modernization Study: Report to Congress*, Washington, DC: National Oceanic and Atmospheric Administration, National Geodetic Survey, June 1998 http://www.ngs.noaa.gov/PUBS_LIB/1998heightmodstudy.pdf

Federal Geographic Data Committee, *National Spatial Data Infrastructure Strategic Plan, 2014-2016*, December 2013 https://www.fgdc.gov/nsdi-plan/nsdi-strategic-plan-2014-2016-FINAL.pdf

Fiducial Points Consulting, *Geodetic Advisor Options and Implementation Scenarios Report*, September 30, 2015.

Geospatial Media and Communications, *Geobuiz: Geospatial Industry Outlook & Readiness Index, 2018 Edition*, https://geobuiz.com/geobuiz-2018-report.html

Hickling Arthurs Low, *et*. *al*., Canadian Geomatics Environmental Scan and Value Study, Summary Report, Prepared for Natural Resources Canada, March 22, 2015 http://ftp2.cits.rncan.gc.ca/pub/geott/ess_pubs/296/296426/cgdi_ip_41e.pdf

Higgins, Matt, "Queensland Australia, the Smart Choice for GNSS," slides, Queensland Government, n.d. http://www.nrw.qld.gov.au/gnss/events/pdf/systems_matthiggins.pdf

Howe, Bret, "National Geodetic Survey Stakeholder Engagement Update," HSRP, October 2014 https://www.nauticalcharts.noaa.gov/ocs/hsrp/archive/2014/sept/webinar/Brett%20Howe%20HSRP%20webinar%20NGS%20Outreach_HSRP_Oct%202014.pdf

International Federation of Surveyors (FIG), *Cost Effective GNSS Positioning Techniques*, FIG Commission Publication 49, FIG Commission 5, 2010 http://www.fig.net/pub/figpub/pub49/figpub49.pdf

K. U. Leuven Research & Development, *Spatial Applications Division, Spatial Data Infrastructures in Europe: State of Play D4.2 - Summary Report Regarding the Results of the European Assessment of 34 NSDI (second year)*, Spring 2011 http://inspire.ec.europa.eu/reports/stateofplay2011/INSPIRE__NSDI_SoP_-_Summary_Report_2011_-_v6.2.pdf

Konecny, Gottfried, "Economic Considerations for Photogrammetric Mapping," International Archives of the Photogrammetry, Remote Sensing and Spatial Info Sciences, Vol. XXXVII, Part B6A, Bejing 2008, pp.207-212 http://www.isprs.org/proceedings/XXXVII/congress/6a_pdf/6_WG-VI-6/04.pdf

Klatt, Calvin, "A Survey of Surveys: The Canadian Spatial Reference System Precise Point Positioning Service," *Geomatica*, September 6, 2017 http://pubs.cig-acsg.ca/doi/abs/10.5623/cig2017-103

Klatt, Calvin, "Estimating Benefits to Canada and the World: The Canadian Spatial Reference System, Precise Point Positioning Service," *Geomatica*, September 6, 2017 http://pubs.cig-acsg.ca/doi/abs/10.5623/cig2017-104

Konecny, Gottfried, "Economic Considerations for Photogrammetric Mapping," International Archives of the Photogrammetry, Remote Sensing and Spatial Info Sciences, Vol. XXXVII, Part B6A, Bejing 2008 http://www.isprs.org/proceedings/XXXVII/congress/6a_pdf/6_WG-VI-6/04.pdf

Leveson Consulting , *Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D*, January 2009 http://www.ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf

Leveson Consulting, *Socio-Economic Study: Scoping the Value of NOAA's Coastal Mapping Program*, report to the Remote Sensing Division, National Geodetic Survey, National Oceanic and Atmospheric Administration, March 8, 2012 https://geodesy.noaa.gov/PUBS_LIB/CMP_Socio-Economic_Scoping_Study_Final.pdf

Leveson, Irving, *Current U.S. Economic Benefits of the Global Positioning System*, Interim Report to the National Coordination Office for Space-Based Positioning, Navigation and Timing, The Aerospace Corporation, March 16, 2010 (internal).

Leveson, Irving, *GPS Civilian Economic Value to the U.S., Interim Report*, prepared for the National Executive Committee for Space-Based Positioning, Navigation and Timing, August 31, 2015 http://www.performance.noaa.gov/wp-content/uploads/2015-08-31-Phase-1-Report-on-GPS-Economic-Value.pdf

Leveson, Irving, "The Economic Value of GPS," *GPS World* (September 2015), pp.36-42 http://gpsworld.com/the-economic-benefits-of-gps/

Mackay, Ross, "Roles and Responsibilities of the NGS Regional Geodetic Advisors, State Geodetic Coordinators and Geodetic Partners," National Geodetic Survey, June 17, 2016.

Malaga Demonstration & Learning Center, "Road Construction Production Study," Caterpillar, December 2006.

Montana Department of Transportation, Height Modernization – Pilot Project," January 9, 2007.

National Academy of Sciences, *Precise Geodetic Infrastructure: National Requirements for a Shared Resource*, National Academies Press, 2010 https://www.nap.edu/catalog/12954/precise-geodetic-infrastructure-national-requirements-for-a-shared-resource

National Council of Examiners for Engineering and Surveying, *2016 Squared*, http://2016.nceesannualreport.com/wp-content/uploads/sites/4/2016/02/Squared-2016.pdf

National Council of Examiners for Engineering and Surveying, *2017 Squared*, https://ncees.org/wp-content/uploads/Squared-2017-web.pdf

Trunick, Perry, "Putting Geospatial Training on Track," *POB*, April 1, 2017 https://www.pobonline.com/articles/100827-putting-geospatial-training-on-track

U.S. Bureau of the Census, *Economic Census* (every five years) https://www.census.gov/EconomicCensus

U.S. Bureau of Labor Statistics, *Occupational Outlook Handbook* (annual) https://www.bls.gov/ooh/

U.S. Executive Office of the President, Office of Management and Budget, North American Industrial Classification System, United States, 2017 https://www.census.gov/eos/www/naics/2017NAICS/2017_NAICS_Manual.pdf

U.S. National Oceanic and Atmospheric Administration, National Geodetic Survey, *2017 Geospatial Summit: Modernizing the National Spatial Reference System*, NOAA Special Publication NOS NGS 12, Silver Spring, April 24-25, 2017 https://www.ngs.noaa.gov/library/pdfs/SP_NOS_NGS_12.pdf

U.S. National Oceanic and Atmospheric Administration, National Geodetic Survey, information page on roles and responsibilities for the three types of participation in the Regional Geodetic Advisor Program, June 17, 2017 (internal).

U.S. National Oceanic and Atmospheric Administration, National Geodetic Survey, *National Height Modernization Strategic Plan*, December 2012.

U.S. National Oceanic and Atmospheric Administration, National Geodetic Survey, NOAA's "National Geodetic Survey Regional Geodetic Advisor Project Plan," Version 4.1, September 2015 (internal).

U.S. National Oceanic and Atmospheric Administration, National Geodetic Survey, *Ten-Year Strategic Plan, 2013-2023, Positioning America for the Future*, n.d.

U.S. National Oceanic and Atmospheric Administration, National Ocean Service, "ACS Position Description, Regional Advisor, update, Geodesist," March 7, 2017.

U.S. Office of Management and Budget, "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs," Circular A-94, October 29, 1992 https://www.wbdg.org/FFC/FED/OMB/OMB-Circular-A94.pdf

United Nations Economic and Social Council, *Spatial Data Infrastructure (SDI) Manual for the Americas*, Report of the Permanent Committee for Geospatial Data Infrastructure for the Americas, Tenth United Nations Regional Cartographic Conference for the Americas, New York, August 19-23, 2013 https://unstats.un.org/unsd/geoinfo/RCC/docs/rcca10/E_Conf_103_14_PCIDEA_SDI%20Manual_ING_Final.pdf

Wisconsin Department of Transportation, "Wisconsin Height Modernization Program," November 2004 http://ngs.woc.noaa.gov/heightmod/publications.shtml

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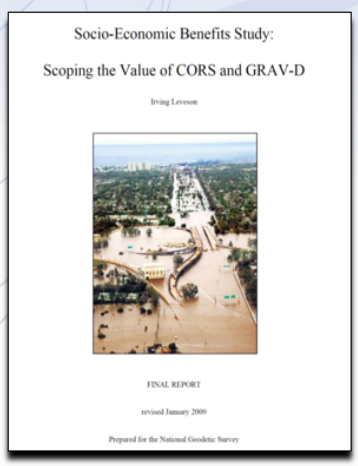
Previous Studies for NGS by the Technical Lead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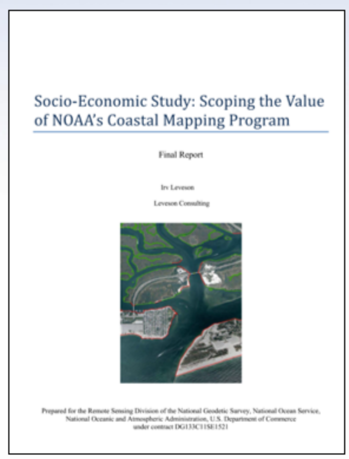
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Final Report

Irv Leveson

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