An Economic Impact Analysis
of the
Indiana Geological Survey

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EXECUTIVE SUMMARY

The Indiana Geological Survey (IGS) is a vital tool for stakeholders across Indiana. Not only does the IGS provide technical information for discovering, developing, and preserving the mineral, energy, and ground water resources of Indiana, but it reduces environmental risks to the health, safety, and welfare of Indiana residents. This report seeks to identify and value the information and services that the IGS provides to the public, private, and non-profit sectors in order to estimate the economic benefit to Indiana.

As a result of a survey of IGS users and input-output economic modeling, this paper conservatively estimates an annual economic impact of **$110.4 Million** on the State of Indiana from IGS activity. This figure includes several different components. First, those who rely on the IGS for information receive it at a steep discount, and thus save considerable costs. These cost savings amount to $29.8 million annually. Additionally, many projects that require geological information could not be completed without the IGS; these projects are valued at $56.2 million per year. Finally, an analysis of industry and expenditure data estimated $24.5 million per year in added impact from secondary market effects.

According to the results of the survey of IGS users, 58% of users reported that the information acquired through the IGS is crucial for project success. The IGS provides a wealth of information through its online research tool, geology databases, and additional services, which are provided to users at no or minimal costs. Beneficiaries of the IGS include the private sector, government agencies, educational institutions and the general public. By providing accurate geological information in this way, the IGS provides a public good to the State.

Researchers at every major university across Indiana utilize the IGS. Oftentimes, this research complements the work done by the IGS, helping to build a better understanding of Indiana's natural resources, such as coal, natural gas, limestone, and water. In addition, the IGS engages in education and outreach by supporting earthquake preparedness, promoting understanding of Indiana's industry, and providing lesson plans to K-12 teachers.

The IGS has fulfilled a vital role in Indiana since its inception. Going forward, its mission and activities must adapt to meet the ever-changing needs of the State. This shift will bring different staffing needs, and will require the IGS to expend significant resources in additional research, mapping, and outreach. While the nature of the IGS's work will continue to change, its economic impact on Indiana will continue to be substantial. [1]

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[1] This study was registered with Indiana University's Institutional Review Board. IRB Protocol# 170230331.

INTRODUCTION

Since its establishment in 1837, the Indiana Geological Survey (IGS) has provided technical information for discovering, developing, and preserving the mineral, energy, and ground water resources of Indiana, as well as reducing environmental risks to the health, safety, and welfare of Indiana residents. The information and services that the IGS provides to the public, private, and non-profit sectors alike provide an environmental and economic benefit to Indiana through risk minimization and project support.

The purpose of this study is to identify and estimate the economic contribution of the IGS to the state of Indiana through the IGS's information, services, and products. This report is intended to inform IGS clients and stakeholders, including the Indiana State Legislature, about the value of IGS activities to all sectors within Indiana.

In order to evaluate the impact of the IGS on the state of Indiana, we implemented a survey of IGS users (henceforth known as the "IGS User Survey") and interviewed a variety of stakeholders throughout the state. The IGS User Survey was conducted over a three-week period and gathered information from users who had been in contact with the IGS over the last two years (and had a valid email address on file). The IGS User Survey utilized an avoided-cost methodology. Users were asked a variety of questions that sought to explain how they use the IGS and how valuable its information is to their work. For more information about the survey methodology and response rate, see Appendix B. Interview subjects were selected to represent each sector and to gather a variety of perspectives. For more information on these interviews, refer to Appendix C. These tools will be utilized and referenced throughout this report to demonstrate who uses IGS resources, what those resources are used for, and what economic impact the IGS has on the state of Indiana. In addition to these information gathering tools, an IMPLAN input-output (I-O) model was utilized to help quantify the full economic impact generated by the IGS.

The main objectives of this economic analysis are to estimate the value of IGS activities to Indiana – its government, private actors, and general populace – and to facilitate a greater understanding of the diverse contributions of IGS activities to various users. This report has six sections: (1) Background information that characterizes the impact of IGS activities in light of dynamic environmental conditions, (2) A review of prior research and methodologies of the valuation of geological information and knowledge creation (3) A descriptive evaluation of IGS user tools, (4) Estimates of the economic value of IGS services to past IGS clients, and (5) The estimated economic impact of IGS activities to the state of Indiana. Finally, section (6) provides a summary of our findings.

I. BACKGROUND AND CONTEXT

A. THE INDIANA GEOLOGICAL SURVEY: AN OVERVIEW OF MISSION AND ACTIVITIES

Figure A: The IGS Mission

The Indiana Geological Survey was officially created in 1837. Since then, the IGS has been housed within the State Board of Agriculture, Department of Conservation, and Department of Natural Resources. However, in 1993, an Indiana statute transferred the IGS to Indiana University, where it has remained since.[2]

The IGS is committed to providing unbiased earth science information through directed research, service, and education. Its mission is threefold: to pursue excellence in geoscience research, to acquire and preserve geoscience materials information, and to serve the public geoscience community. To fulfill its mission, the IGS provides and assists users with geological information on a wide range of research areas, including Energy, Water, Minerals, Geological Materials, Environmental Geology, and Geologic Hazards.[3] The value created by the IGS stems from the diversity of its research topics and the variety of its research tools. Figure B below identifies a few of the IGS's available digital tools and offline services. These services are critical to a variety of stakeholders, yet most are provided for free or at-cost.

Figure B: IGS Services

	Service	Description	Initial Cost	Premium Cost
Digital Services	**IGS Map**	Interactive web application that showcases Indiana's energy, water, and hazards of the state's geology.	Free	-
	IndianaMap	GIS web application that allows users to explore, visualize, and share custom Indiana maps and GIS information.	Free	-
	Aerial Maps (IHAPI)	Interactive map to allow for retrieval of historical aerial photographs previously only available in person in the archives.	Free	-

2 Indiana Geological Survey (2017). "Who We Are." *Retrieved from* https://igs.indiana.edu/About/WhoWeAre.cfm.
3 Indiana Geological Survey (2017). "Our Mission Statement." *Retrieved from* https://igs.indiana.edu/About/MissionStatement.cfm.

	Petroleum Database (PDMS)	Database on more than 70,000 petroleum-related well locations, logs, operations, leases, tests, samples, and cores for drilled in Indiana.	Free	$500/yr
	Geological Names Information System	Database of geologic units of stratigraphic name, rank, and order recognized by IGS.	Free	-
	Coal Mine Information System (CMIS)	Repository of historical documents, prepared maps, and reports on coal mining in Indiana.	Free	-
Offline Services	**Consultation**	Consulting service providing by IGS; data retrieval; custom geodatabase; custom map creation.	Free up to 2 hrs	$35/hr - $50/hr
	Records and Data Archives	Archived petroleum records, coal records, industrial mineral reports, gamma-log records, cores and samples.	Free	At-Cost to Copy

Today, users of geological information have an increased demand for immediate and affordable access to the variety of information and tools provided by the IGS. As a result, the IGS has increasingly relied on information technology to provide public databases, geographic information systems, and digital publications that contribute to the feasibility of valuable projects throughout the state. This challenge is not unique to Indiana, and a comparison of the organization, activities, staffing, and funding of various geological surveys reveals that the IGS is typical of other state surveys.[4]

B. Indiana Geological Survey: Financial Appropriation and Staffing

The success of the IGS mission relies on the quality of its staff and its funding resources. The majority of IGS funding stems from an annual state appropriation. In 2016, the IGS received about $2.8 million, which represented approximately 80 percent of its total budget for the fiscal year.[5] The remaining fund obligations were covered through contracts, grants, and user fees. However, as shown above and discussed in detail below, user fees represent a nominal contribution to total budget revenue. Figure C provides a comparison of the state appropriation to staff levels, while Figure D (below) emphasizes the decline in contract and grant funding in the last decade.

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[4] For more information on how the IGS compares to other state geological surveys, see appendix A.
[5] Data received directly from the Indiana Geological Survey, Division of Business Affairs.

Figure C: State Appropriations and Staffing for IGS (1992-2017)[6]

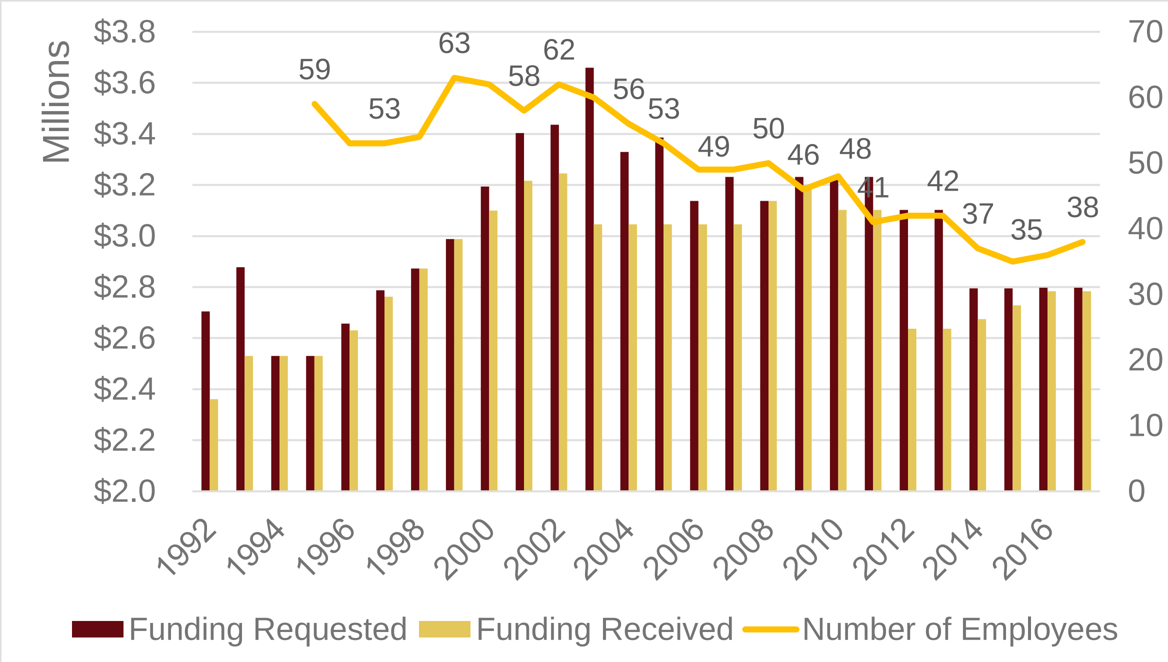

Figure C illustrates how state appropriations for the IGS have diminished beginning in 2012 and continuing through 2017. Across this time period, the IGS received an average annual state appropriation of approximately $2.8 million. Figure C also shows decreasing staff levels over the same period of time. Between the mid-1990s to the early 2000s, the IGS employed some 60 staff members, though since 2003 numbers have fallen to the current state of about 40 employed staff. The reduction in staff has led to the redistribution of priorities and forced the IGS to forgo important—yet unaffordable—research areas like water resources.

In addition to demonstrating the trend in state appropriation and staffing, Figure D shows the related decrease in contract and grant funding. Since a peak of $2 million in contracts and grants in 2004, the IGS has experienced a 50 percent decrease in contract and grant funding, which currently sits at a decade low. These decreases in funding, as a result of state appropriation cuts and reduced grant and contract revenue, have forced the IGS to reduce staff and services, and they present the IGS with significant challenges in fulfilling its mission.

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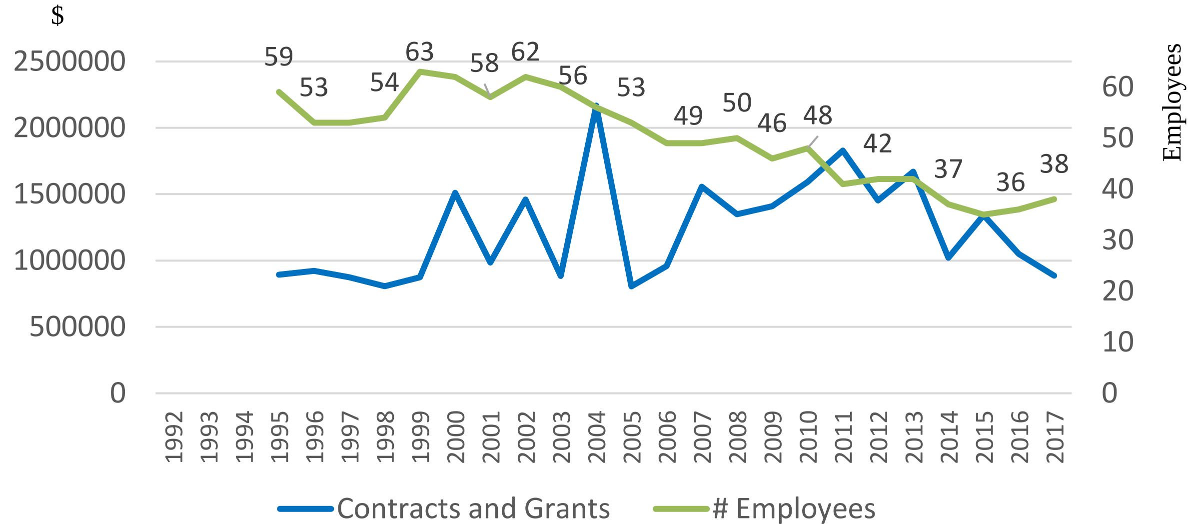
[6] Data and graph provided by and on file with the Indiana Geological Survey.

Figure D: Decline in Contract, Grants, and Staff for IGS (1992-2017)[7]



C. Comparison to Other State Geological Surveys

As mentioned, the challenges facing the Indiana Geological Survey are not unique. Surveys and geological information providers throughout the country face challenges relaying the importance of geological information to various stakeholders. The following section compares the IGS to other geological surveys with regard to (1) the activities, services, and type of organization; (2) the number of staff; (3) the number of geologists; (4) the ratio of the numbers of geologist to the numbers of staff; and (5) total funding in 2016.

1. Activities, Services, and Type of Organization

Regarding the activities and services provided, state geological surveys generally offer similar services associated with geological information. This means they share the same basic mission in utilizing geological science to contribute to sustainable socio-economic development in the public interest. In a 1988 Association of American State Geologists (AASG) project to provide a summary on the history of the state geological surveys, Socolow agreed that "while they are diverse in size, in name, and in detailed functions, each has the basic responsibility to delineate the geological resources and conditions as they impact upon the economic and environmental well-being of the respective state."[8]

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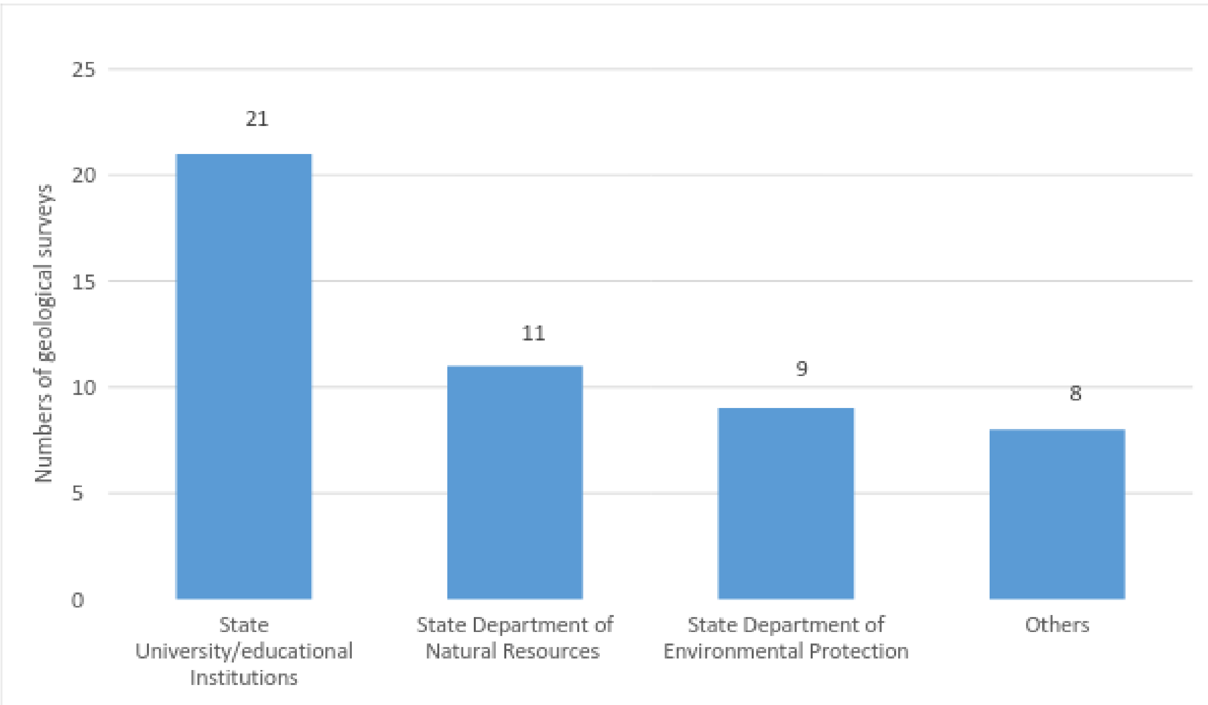
[7] Data and graph provided by and on file with the Indiana Geological Survey.

[8] Socolow, A. (1988). The State Geological Surveys – A History. Retrieved March 31, 2017 from http://www.stategeologists.org/tmp/aasg_1236116366.pdf

Although state geological surveys work in the same fields, the way in which they are organized varies widely. To compare different organizational structures, we categorized state geological surveys by the type of state agency, department, or institution to which these geological surveys belong. This information was largely collected from geological surveys' websites or found through AASG's website. Figure E below presents these different structures.

Figure E: Type of Organization of the State Geological Surveys[9]



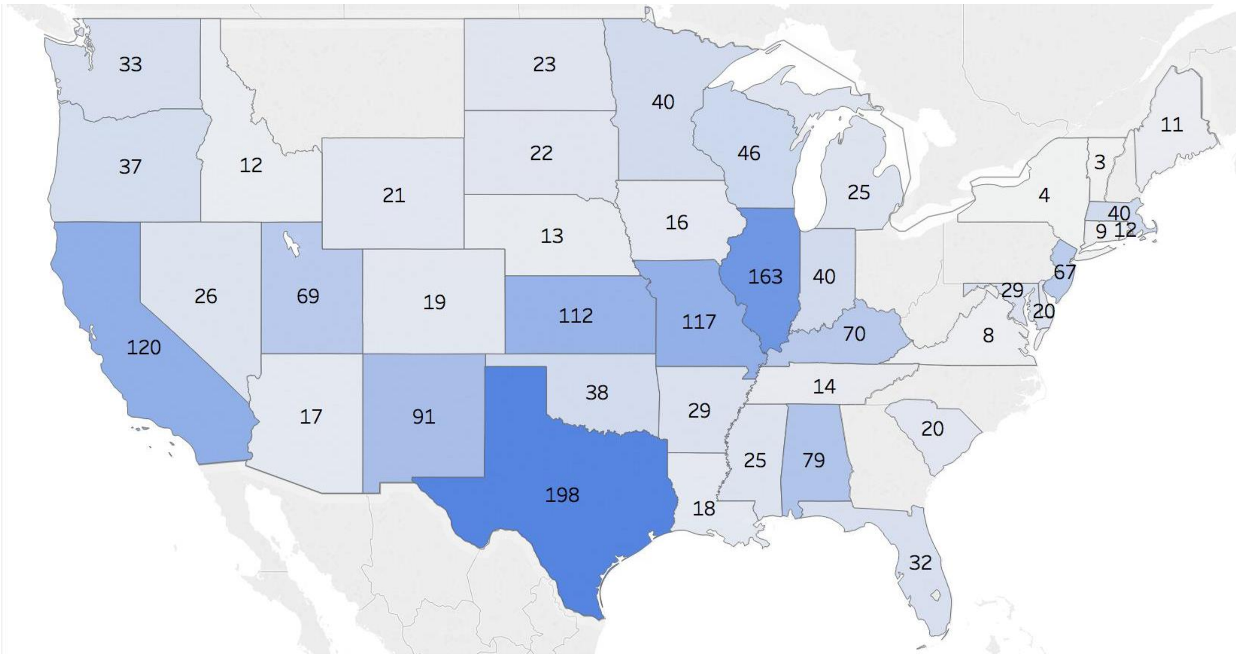
Forty-nine states have their own state geological survey; Hawaii is the only state that does not operate its own geological survey, which is instead run by the federal government. Of these, 21 state geological surveys (including the IGS) are organized as part of state universities or educational institutions, making this the most popular organization type. Figure E illustrates that 11 geological surveys belong to the state's department of natural resources and nine geological surveys are managed by a state department of environmental protection. We categorize eight geological surveys as "others" because we are unable to find a broad term to define their organizational structure. The term "others" here include various types of organization. For example, the geological survey of Alabama is a part of the Alabama State Oil and Gas Board, and New York State Geological Survey is part of the New York State Museum.

The IGS is also similar to other surveys and geological service providers throughout the country

9 Association of American State Geologists (2017). State Geological Surveys. *Retrieved from* chttp://www.stategeologists.org/surveys.php.

in terms of staffing and funding. Figure F below shows the staffing level for state geological surveys throughout the country. Compared to nearby states with similarly sized populations such as Kentucky, Michigan, and Wisconsin, Indiana is not an outliar in terms of staffing. Unsurprisingly, large states such as Illinois, Texas, and California have the largest geological survey staffs.

Figure F: Comparison of Geological Survey Staffing Numbers[10]



Note: For states without staffing levels shown, information could not be acquired.

10 Information assembled by the Capstone Class from state geological survey websites during March, 2017.

II. REVIEW OF OTHER VALUATION PROJECTS

A wide breadth of literature is available on the value of geological information, both from academic and professional sources. Academic research has largely centered around proving the importance of this information to various stakeholders, and attempting to value it using different methodologies. Geological information has historically enjoyed use in diverse areas of application, supporting private industry and government services alike. This allows for many real-world examples on which academic research can be based.

We review here the current literature on this subject, using both academic work and professional examples, beginning with a conceptualization of geological information's economic properties. An overview of the work proving the importance of geological information follows, including an evaluation of its use in risk mitigation and cost minimization. We then review research related to the valuation of geological information, namely those utilizing different methodologies to present a dollar figure value; this research provides the conceptual framework for the work within this report on the valuation of the Indiana Geological Survey. We end with a review of the literature on the challenges to current valuation efforts—such as the difficulty of valuing knowledge creation—and a discussion of the future of valuation studies as they relate to geological information.

In conceptualizing geological information, we can consider it as sharing economic characteristics of a public good—in that it is nonrival[11]—and an experience good, given its role not as the final product but as a component in the creation thereof.[12] Geological information can also be non-exclusive when downloaded and shared, given its digital dissemination and use properties. Although the information's costs are simple to determine in terms of staff, database maintenance, and distribution, the information's economic characteristics make it difficult to effectively price in economic markets, a situation disincentivizing its private provision.[13] Thus, governments play a significant role in providing geological information, as evidenced clearly by the practice of geological surveys furnishing this information in nearly every state. This difficulty to effectively price information distorts valuation efforts using cost data.[14] Considering geological information in this sense serves as the foundation for determining how to value it accurately, as the acknowledgement of unreliable market pricing leads us to consider alternate methods. These considerations are discussed below, beginning with works illustrating the existence of the value of geological information, followed by works attempting to monetize this value.

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11 Pearlman, F., Pearlman, J., Bernknopf, R., Coote, A., Craglia, M., Friedl, L. Smart, A. (2016). Assessing the Socioeconomic Impact and Value of Open Geospatial Information: US Geological Survey Open-File Report 2016.

12 Häggquist, E., & Söderholm, P. (2015). The Economic Value of Geological Information: Synthesis and Directions for Future Research. *Resources Policy*.

13 Ibid 12.

14 Ibid 12.

A. The Importance of Geological Information

Many relevant professional examples involve providing an indication of the importance of geological information to stakeholders, both public and private. In searching for such examples, one need travel no farther than Evansville, Indiana, home of the Modified Mercalli Intensity for scenario earthquakes. Several times over the past 200 years, the area around Evansville has witnessed earthquake damage, given its proximity to the Wabash Valley and New Madrid seismic zones.[15] To combat the threat of future earthquakes to the area, scientists from the United States Geological Survey (USGS) created a system to estimate "how strongly the ground is likely to shake as a result of an earthquake," assisting "the region [to] prepare for future earthquakes and reduce earthquake-caused losses."[16] This information would likely have not been provided by the private market, yet it works to create valuable improvements to public safety and cultivates understanding of the vulnerabilities to public goods, such as infrastructure susceptibility.

In a similar vein, the New Madrid Seismic Zone Catastrophic Earthquake Response Planning Project analyzed the hazard, inventory, and vulnerability of several states to earthquakes, using geological information to compute potential loss. The results from this study were designed to provide emergency managers and agencies with the data to create hard response plans, protecting against up to $56 billion in potential losses in Tennessee alone.[17] These types of studies are conducted throughout the United States and the rest of the world, and are not limited to safety improvements, as illustrated in the Geological Survey of Canada and USGS's joint analysis of geological information's effect on mineral exploration efficiency. The researchers have found that geological map availability improves mineral exploration efficiency, effectiveness, and productivity, increasing targets and decreasing search effort.[18] It is evident that these and other studies result in a myriad of benefits to the public and private sectors. Ascribing a valuation, however, can allow governments and stakeholders to gauge the return on investment of its provision, as well as compare different project alternatives.

B. Risk Mitigation and Minimization

Literature on the use of geological information also provides insight to risk mitigation and

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15 Cramer, C., Haase, J., & Boyd, O. (2012). Modified Mercalli Intensity for Scenario Earthquakes in Evansville, Indiana: U.S. Geological Survey General Information Product. 138. 91-100.

16 Ibid 15.

17 Elnashai, A. S., Cleveland, L. J., & Jefferson, T. (2008) Impact of Earthquakes on the Central USA. *New Madrid Seismic Zone Catastrophic Earthquake Response Planning Project*. Rep. no. 08-02. FEMA.

18 Bernknopf, R., St-Onge, M., & Lucas, S. (2007) Analysis of Improved Government Geological Map Information for Mineral Exploration: Incorporating Efficiency, Productivity, Effectiveness, and Risk Considerations. (Rep. No. 1721).

minimization. Geological information can save money for stakeholders, such as city planners and private sector actors in various resource industries. Risk minimization and mitigation further indicate the importance of geological information, and real-world examples are numerous. A California Geological Survey study used geographic information system (GIS) technology to conduct a viability assessment for the California State Parks Off-Highway Motor Vehicle Recreation Division. It sought to analyze a Bakersfield property as a possible State Vehicle Recreation Area (SVRA), with the special purpose of understanding the presence of *Coccidioides immitis*, a pathogenic fungus that causes valley fever.[19] Geological information was used to assess the erosion hazard potential of the property soils, and the relative likelihood of the fungus's presence. In doing so, the California Geological Survey effectively contributed to "natural resource management and disaster mitigation efforts,"[20] using geospatial information in tandem with modeling processes to minimize risk to human life.

In a similar fashion, the California Geological Survey studied alluvial fan flood plains, for which studies are rarely conducted by the Federal Emergency Management Agency (FEMA) in undeveloped areas and are often unavailable for long-term planning.[21] In doing so, the California Geological Survey was able to assist in the evaluation and planning of proposed development sites, evaluating flood risk and allowing "planners, developers, and homeowners to avoid the development of hazardous areas."[22] These types of studies, although undeniably useful in minimizing and mitigating risk to many stakeholders, do not necessarily provide a valuation for the geological information or its benefits. Instead, they illustrate the role geological information can play in *ex ante* settings, and further expound the existence of geological information's benefits to society.

Attempting to apply risk considerations to benefit valuations, Bernknopf and Shapiro assigned geospatial information as an input for earthquake housing risk concentration in Southern California.[23] In their study, they found that decision makers require a way to prioritize investments in risk mitigation. In essence, their valuation sought to identify the degree to which damages from natural disasters could be reduced if local ordinances considered geospatial information. By using an earthquake simulator to model hypothetical scenarios, the government could shape building ordinances to minimize risk. Through the use of geologic information, "a retrofit building code for multi-family buildings could identify where public intervention and

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19 Harris, W. J., & Roffers, P. D. (2012) Assessing Erosion Potential and Coccidioides Immitis Probability Using Existing Geologic and Soils Data.

20 Ibid 19.

21 Lancaster, J. T., Spittler, T. E., & Short, W. R. (n.d.). Using Digital Geologic Maps to Assess Alluvial-Fan Flood Hazards.

22 Ibid 21.

23 Bernknopf, R., Shapiro, C. (2015). Economic Assessment of the Use Value of Geospatial Information. *ISPRS International Journal of Geological Information*. 1142-1165.

investment would be cost effective."[24] As a result of the Los Angeles County application, they calculated benefits as the potential savings from risk mitigating and cost minimizing regulation from half a billion to 1 billion dollars.[25] As such, the researchers were able to equate savings from risk mitigation to the benefits of geological information, exemplifying a possible valuation methodology from risk considerations. This can also be considered as part of a broad valuation methodology, whereby benefit valuations are found through the calculation of geological information's influence on improvements to decision making, discussed below.

C. Improvements to Decision making

A second branch of academic research and professional application relating to the value of geological information includes work to calculate and present dollar figure valuations. This is primarily done through revealed preference and stated preference studies, either through finding improvements to decision making as a result of the geological information, or calculating a stakeholder's avoided costs. To note, revealed preference studies assume that that preferences can be revealed through consumer behavior, while stated preference studies approach this by relying on survey questions, which ask consumers to indicate their preferences explicitly. Improved decision-making can impact a wide range of stakeholders, from private companies analyzing mineral exploration to governments exploring site selection. To value geological information under this framework, researchers need to have available the losses averted from having access to the information, and possibly a measure of the reduction in uncertainty.[26]

Bernknopf and Shapiro outline this methodology as "innovative application," arguing that the decision framework must be able to differentiate between the decision maker's actions before and after the new information.[27] In their study on geospatial information for regional environmental and policy decisions Bernknopf and Shapiro examine the use of geological information on government regulation and find that the value of information (VOI) can be found through the increase in agricultural production and reduction in environmental impacts from use of moderate resolution land imagery to increase regulation efficiency.[28] This improved decision making resulted in efficiency improvements and a commensurate valuation of approximately $38 billion.

The USGS has itself developed a model for predicting the benefits of GIS technology that incorporates improvements to decision making. The general framework assesses efficiency and

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24 Ibid 23.
25 Ibid 23.
26 Ibid 23.
27 Ibid 23.
28 Ibid 23.

effectiveness benefits, with efficiency referring to achieving the same output at a lower cost, and effectiveness meaning improving the quality of a current output or producing an output previously unavailable.[29] Theoretically, this is summarized as the value of the output with GIS minus the value of the output without GIS, plus the difference in cost with and without GIS.[30] However, of the four terms in such a formula, the cost of the project without GIS "is the only one for which a government agency is likely to have reasonably accurate information."[31] Although it should be theoretically straightforward to assess the benefits of the information, in practice, the information hurdles are likely too large for most government agencies attempting to assess benefits more accurately. GIS thus uses a pair of ordinary least squares multivariate regression equations to circumvent the information issues, substituting these direct inputs with measures of input, analysis, and output complexity. The result is an explanatory power anywhere from one-half to three-fourths of measured variation of GIS benefits.[32] When a similar efficiency/effectiveness model was applied to the Illinois Department of Transportation's (IDOT) GIS implementation, assessing improvements from automation of previous manual efforts as well as improved decision making, it contributed to a cost-benefit net present value calculation of $2.9 million and an internal rate of return of 99.8 percent.[33] To support this, Bernkopf et al. find that geological map information has a net positive value to society, primarily through allowing planners to make superior land management decisions from a regulatory perspective.[34]

It is evident through these examples that improved decision making has a strong academic and professional history as a method of valuing geological information, and several researchers have advocated for different ways to apply the information: for regulatory efficiency, for cost-benefit analysis before undertaking a project, and for ex-post project evaluations. However, the lack of access to information is a potentially serious disadvantage to this method. As mentioned, for many government agencies, it is not worthwhile to collect the large amounts of information needed to complete a valuation analysis using improvements to decision making. It is easier to rely on a simpler methodology, cost avoidance, that has a similarly strong academic background and history of recent professional application, albeit with far fewer time and monetary requirements.

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29 Gillespie, S. R. (2000). An Empirical Approach to Estimating GIS Benefits. *Journal of the Urban and Regional Information Systems Association.* 12(1), 7-14.

30 Ibid 29.

31 Ibid 29.

32 Ibid 29.

33 Hall, J., Kim, T., & Darter, M. (2000). Transportation Research Record. *Journal of the Transportation Research Board*. 1719, 219-226.

34 Bernknopf, R. L., Brookshire,D.S., McKee,M., & Soller, D. R. (1997). Estimating the Social Value of Geologic Map Information: A Regulatory Application. *Journal of Environmental Economics and Management*. Volume 32, Issue 2, Pages 204-218, ISSN 0095-0696.

D. Avoided Cost

Bhagwat and Berg, economists for the Illinois State Geological Survey, prepared one of the first valuations of geological information in 1992, focusing their efforts on its value to the Illinois counties of Boone and Winnebago.[35] Using a benefit cost framework, they calculate avoided costs for cleanup of waste disposal and industrial contamination sites as a primary benefit of mapping. Bhagwat and Ipe brought this avoided cost methodology to their own report in 2000, assessing geological information's value to the state of Kentucky. In their study, they acknowledge the diverse purposes for which geological information can be used, including mineral exploration, consulting, and city and regional planning. Their study employs a methodology that assumes, given that map users are risk-neutral, the map user's objective is "to minimize the expected total cost of preparing a given quality project report."[36] The expected cost of a report for a map user, or decision-maker using the geological information for a project, is reflected in the equation below as *EC,* and is a function of *T*, the effort put into preparing the report with the geological information available; α, the geological information available at the time of report preparation; and *R*, the report's credibility.

$$EC(T,\alpha,R) \text{ where } \frac{\partial EC}{\partial T} > 0, \quad \frac{\partial EC}{\partial \alpha} < 0, \quad \frac{\partial EC}{\partial R} > 0$$ [37]

An increase in α is the only variable in the equation that will diminish expected costs when raised. The goal of the decision-maker, according to the researchers, is to select the effort level, *T*, to minimize expected costs while still maintaining the necessary level of credibility to move forward with a project. Therefore, given two scenarios, one in which geological information is not available, and one in which it is, the decision-maker will receive a more credible report at a lower cost when the geological information is available. When it is not available, greater effort, *T*, will need to be put into acquiring it, raising expected costs. The difference between the expected costs with and without geological information can be considered the expected savings to the decision maker and is reflected in the equation:

$$ES = EC\left(T_p^*, \alpha_p, \overline{R}\right) - EC\left(T_m^*, \alpha_m, R\right)$$ [38]

This theoretical framework provides the methodological justification through which geological information valuation studies can employ surveys, with the goal of deriving a figure for avoided costs. The final equation implies that in the absence of provided geological information,

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35 Bhagwat, S.B. & Berg, R.C. (1992). Environmental Geology Water Science. DOI: 10.1007/BF01740575

36 Bhagwat, S., & Ipe, V.C. (2000). Economic Benefits of Detailed Geologic Mapping to Kentucky. Special Report No. 3. *Illinois State Geological Survey*.

37 Ibid 36.

38 Ibid 36.

decision-makers would need to collect this information themselves in order to meet the credibility threshold necessary to complete projects. By providing information publicly, as the Indiana Geological Survey does, it allows its users to avoid costs that would otherwise need to be incorporated into the total project cost. The value of geological information, following this logic, is equal to the avoided costs calculated.

Miller et al., in a study for the USGS, utilize this same methodological model to assess Landsat and moderate-resolution satellite imagery throughout the country.[39] Several other studies have built upon this methodology, recognizing not only the avoided cost of acquiring the information, but also the economic and environmental losses avoided as a component of geological information valuation.[40] [41] However, these studies and others of their nature often require certain additional data reflecting revealed preferences, specifically from pre and post-geological information periods; only when these data are fully available is a legitimate comparison possible between the two time periods.

For the purposes of valuing the services and products provided by a geological survey, Bhagwat and Ipe's example, adopted by Miller et al., is the most applicable. It allows the researcher to use survey data in pursuit of valuation instead of revealed preference data for all individual firms throughout the state that use geological information, likely impossible given the scope of such an effort, and at best extremely costly to acquire in time and money. Using their methodology, Kleinhenz and Associates also prepared an economic impact analysis of the Ohio Geological Survey in 2009. Kleinhenz primarily utilized an avoided cost valuation framework and an analysis based on prior research. They supplemented this methodology with an Input-Output economic contribution model known as IMPLAN, as well as a literature review.

This report on the Indiana Geological Survey follows this methodology, employing stated preference surveys applied to avoided cost valuation to calculate the benefits to firms using IGS services and products, in a manner consistent with previous studies of the same purpose. As the valuation of geological information is still a relatively nascent focus of research under the umbrella of valuation methodology, many of its components are still subject to debate among academics and professionals. We review the relevant considerations for improvement, and the criticisms currently discussed, in subsequent sections.

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39 Miller, H.M., Sexton, N.R., Koontz, L., Loomis, J., Koontz, S.R., & Hermans, C. (2011). The Users, Uses, and Value of Landsat and other Moderate-Resolution Satellite Imagery in the United States—Executive report. *U.S. Geological Survey* Report 2011–1031, 43.

40 Ibid 34.

41 Bernknopf, R. L., Brookshire, D. S., Soller, D.R., Mckee, M. J., Sutter, J. F., Matti, J.C., & Campbell, R. H. (1993) Societal Value of Geologic Maps. *U.S. Geological Survey*.

E. Considerations and Criticisms

This review of relevant literature would be remiss if it did not address other considerations that may work to qualify these commonly used valuation methodologies. Literature on these include context specificity, ex-post verification methodology, and issues in valuing knowledge creation and other larger-scale societal benefits. Haggquist and Soderholm argue that the differences in contexts may affect the reliability and validity of valuation assessments.[42] There may be a difference in valuation results for studies that examine improvements to decision making based on more effective insurance pricing and studies that assess those same benefits through a survey to relevant stakeholders. Because of this potential inconsistency, there is reason to explore this issue further, with the hope of determining which methodologies can be applied consistently to scenarios with similar contexts. A recent study on contingent valuation and hedonic pricing related to urban open space found that the methodological difference in study design had a notable influence on estimated valuation; a comparison study of this nature has not yet been conducted in regards to geological information, though it would generally work to increase valuation result validity.

With contingent valuation and willingness-to-pay surveys, there is a susceptibility to bias due to respondent incentives and hypothetical bias, among others. Bias may be found in response incentives, as those who respond may have an incentive to support geological survey services, or they may be those who use the services at a disproportionately higher rate than the general user base. This bias is difficult to counteract, though there are arguments that respondents who use the geological information to a larger degree may work with higher project values (or more frequent projects), and their opportunity cost is consequently too high to respond to a survey. This would cause the respondent sample to undervalue the true benefit. This issue is inherent to surveys in general; however, it can be mitigated through response sample size and survey language, among others factors. There are survey methods to combat this, but bias may remain an issue. Other researchers have attempted to buttress methodological strength by combining models, such as revealed and stated preference methodology.[43] A combination model has the added benefit of accounting for heterogeneity, while limiting the weaknesses of each individual component model.

Another method of combating survey bias is verification of *ex ante* studies with *ex post* assessments. A strength of the *ex post* assessment used in this study of the Indiana Geological Survey is its avoidance of potential bias from unforeseen events, an inherent concern with *ex ante* assessments. This should make this study more accurate, though we recommend verification

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42 Ibid 12.

43 Adamowicz, W., Louviere, J., Williams, M. (1994) Combining Revealed and Stated Preference Methods for Valuing Environmental Amenities. *Journal of Environmental Economics and Management*. Volume 26, Issue 3, Pages 271-292, ISSN 0095-0696.

of future study iterations using any form of *ex ante* assessments with *ex post* assessments to maintain a similar level of validity.

A final consideration in qualifying geological information valuation revolves around the subject of knowledge creation. Knowledge creation is "the creation of new ideas or new innovations, for example, a new product, service or process."[44] This knowledge is derived from the product's development, as well as from its use over time by its developer and those who have access to it.[45] Unlike many publicly provided goods, such as national defense or clean air, geological information lends itself to the ability to foster the creation of new ideas, similar to software development, such as Linux or Windows. Geological information facilitates knowledge-creation as businesses, governments, and academic institutions use it to complete projects and research.

Unfortunately, the practice of measuring knowledge-creation has existed up until now almost entirely within the realm of business,[46] given its applicability to the corporate goals of wealth and innovation. This presents a major challenge to incorporating the clear knowledge-creation potential of publicly-provided geological information to the general public, as the products and services the Indiana Geological Survey provide undoubtedly contribute to innovation and additional benefits beyond the relatively narrow measure of avoided costs.

Academic research is similar in its use and benefits, and there are several aspects by which academic research creates value, such as the accumulation of knowledge, training personnel and developing human capital, addressing practical problems or challenges, and serving as a basis for technology innovations and new scientific instrumentations.[47] All pathways are difficult to measure monetarily, but several studies exist supporting the economic value of academic research. Jaffe (1989) found that university research had significant impact on corporate innovation using university research, corporate patents, and corporate research and development data. Grossman, Reid & Morgan (2001) investigated the relationship of academic research and industrial performance in five different industries and found that even though the university-industry research interaction varies from sector to sector, "academic research has made substantive contributions in varying degrees to the performance of all five industries." Georghiou (2015) summarized different estimates of the economic value of public investment in research, which range from a 200 percent to 800 percent increase from the initial investment.

At the very least, the idenitification of knowledge creation and academic research as qualitatively beneficial indicate that quantitative valuation efforts like those within this study likely

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44 Shongwe, M. (2015). Knowledge-Creation in Student Software-Development Teams. *SA Journal of Information Management.*

45 Ibid 44

46 Mitchell, R., Boyle, B. (2010). Knowledge Creation Measurement Methods. *Journal of Knowledge Management*. Volume 14 Issue: 1. pp.67-82, DOI: 10.1108/13673271011015570

47 Georghiou, L. (2015).Value of Research. *Research, Innovation and Science Policy Experts* (RISE).

undervalue true societal benefits to a certain extent. This knowledge-creation component of this study is captured in part in various other places, such as the roundtable discussions, but to what degree is uncertain and beyond the scope of this report to ascertain. Future studies would do well in exploring this essential societal benefit as it relates to the public sector.

This research suggests that geological information valuation methodology has the tendency to undervalue actual societal benefits. Challenges such as valuing knowledge creation have been addressed in the abstract, with an indication that there are certain benefits or byproducts that are not fully captured in current professional application. This does not enable us to fully incoporate all potential benefits here or in previous studies, like that of the Kleinhenz & Associates Ohio Geological Survey report. However, it allows us to conceptually consider geological information on a societal level, as likely more beneficial than currently considered.

As it applies to this report, our review of current literature finds that the most consistent methodology on benefit valuation centers on revealed or stated preference, with avoided cost-based surveys used in many professional applications. This report follows this avoided cost methodology, using self-reported avoided cost estimates to determine the annualized value of the geological information the IGS provides.

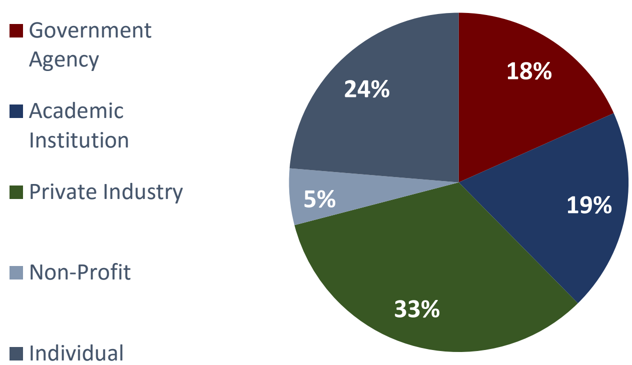
III. Uses and Users of IGS Services

The IGS is a valuable tool for a wide variety of actors throughout the state of Indiana, including government agencies, private industries, academic researchers, and members of the general public. Contextualizing how IGS information and data is used is a key goal of this study, as this knowledge should promote greater understanding of how the IGS provides value throughout the state. In addition to information provided by the IGS, we compiled this information through the IGS User Survey and interviews conducted with various stakeholders.

A. Overview of Findings

The IGS User Survey, described earlier, received over 200 responses from various types of users throughout the state.[48] Figure G describes the breakdown of the respondents by sector. The balanced sector response rate is indicative of what we know about the IGS; its clientele is diverse, and its work is used for a wide variety of purposes.[49]

Figure G: Survey Respondents by Sector



The IGS User Survey also asked to identify the various ways in which they use the information they receive from the IGS, either through request or through web-based tools such as IndianaMap. The result indicated a broad and wide-ranging set of uses; users reported using IGS information for exploration and development, environmental consulting, hazard prevention, engineering applications, planning and zoning, and for property valuation activities. Table 1 (below) shows a breakdown of the various uses of IGS information.

48 The IGS User Survey received 213 responses based on emailing 746 individual email addresses. A link to the survey was also provided on the IGS newsletter. See Appendix B for further discussion of survey methodology.

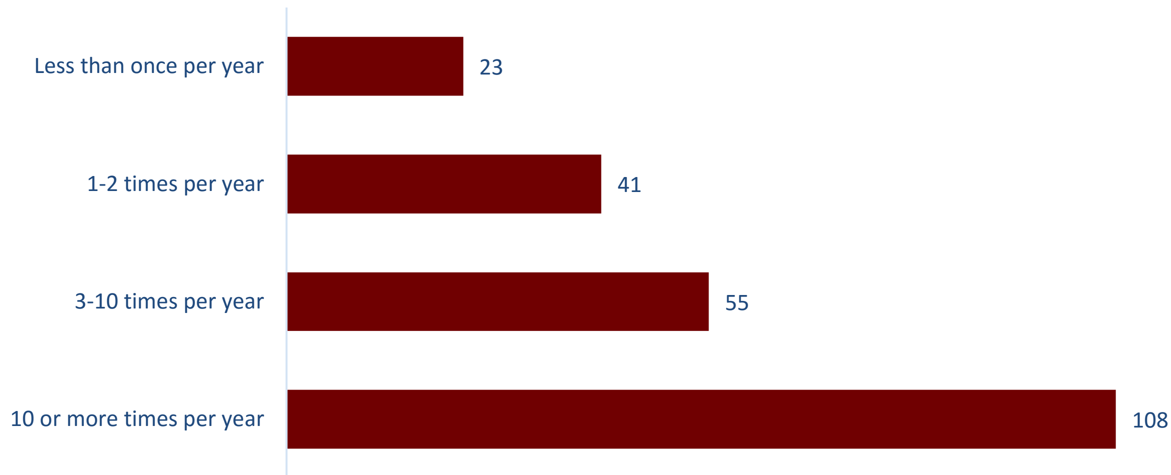
49 For a discussion on the representativeness of the IGS User Survey, see Appendix B.

Table 1: Uses of the IGS

Category	Uses of IGS information	% of all respondents
Exploration and Development	Coal	12%
	Oil and Gas	21%
	Industrial minerals (limestone, sand/gravel, clay)	15%
	Groundwater and surface water	41%
	Other	20%
Environmental Consulting	Clean Air Act	8%
	Safe Drinking Water Act	16%
	Clean Water Act	21%
	NEPA process	21%
	RCRA	12%
	SMCRA	6%
	Other	9%
Hazard Prevention	Landslides	5%
	Earthquakes	11%
	Karst (sinkholes, drainages)	22%
	Subsidence	10%
	Other	7%
Engineering Applications	Buildings and foundation	15%
	Roads/Highways	22%
	Railroads	11%
	Karst (sinkholes, drainages)	19%
	Subsidence	9%
	Other	7%
Planning and Zoning	Zone decisions	7%
	Landscape design and planning	10%
	Building codes	3%
	Waste disposal facilities	14%
	Transportation	18%
	Permitting industrial facilities	12%
	Other	8%
Property Valuation	For tax purposes	4%
	Land acquisitions	17%
	Other	10%

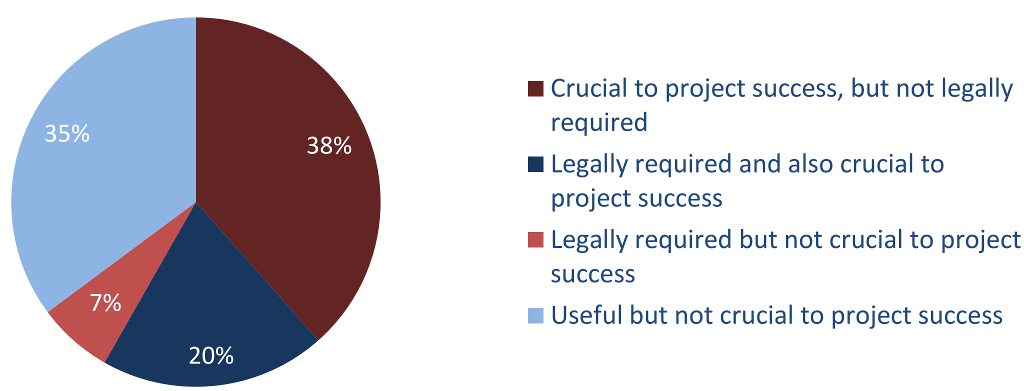
In addition to the broad usage of IGS information, respondents reported using the IGS at a high frequency; nearly 50% of the respondents indicated using the IGS ten or more times per year. Ninety percent of respondents indicated that they make use of IGS information and services on at least an annual basis. This response indicates that users make frequent use of the web-based tools for their work.

Figure H: Frequency of Use



Respondents were also asked how important the information they receive from the IGS is to their work (See Figure I below). Sixty-five percent of respondents indicate that the products they use were either critical to their work or legally required. Only a third of respondents indicated that the information was useful, but not critical or legally required. This response gives a window into the importance of the services and products provided by the IGS. In many cases, users would need to acquire information from another source (which may or may not exist), given the critical and often legally required nature of the information.

Figure I: Importance of Information to Work



B. Government

Eighteen percent of IGS User Survey respondents reported that they represented a government entity. These actors come from local, state, and federal levels. Frequent state users of the IGS include the Indiana Department of Environmental Resources, the Department of Environmental Management, and the Department of Transportation. Examples of typical federal government users include the U.S. Forest Service and the U.S. Geological Survey. All of these agencies rely on the research and data publication work done by the IGS to help improve the accuracy and safety of their work, as well as to help make public information more widely accessible. Per the IGS User Survey, over one-fifth of respondents representing government agencies reported utilizing IGS information for the following activities shown in Table 2.

Table 2: Government Uses

Top Uses – Government Agencies
Groundwater and surface water
NEPA process
Safe Drinking Water Act
Clean Water Act
Karst (sinkholes, drainages)
Roads/Highways
Transportation

These results from the survey are useful for understanding what type of information the IGS provides to government users. However, direct interviews with public sector actors as well as with IGS staff help illuminate the broader purpose for which agencies utilize the IGS. Based on these conversations, public sector users primarily use IGS services and products for health and public safety concerns. For example, government actors are concerned with the quality of drinking water, which is influenced by the nature of minerals and chemicals in the subsurface. One interview subject in the field of public health explained their usage of the IGS:

> *"If we go to the IGS maps of Marion County, we can tell where the New Albany Shale is, which causes higher levels of arsenic in drinking water wells. And if we overlay the other layers in our own GIS that shows where the water lines are, we can outline areas of the county to target with our well sampling because they are over private drinking water wells and they are over the New Albany Shale. Those are the wells we need to go look at. Even a small health department can do that using IndianaMap on IGS."* [50]

Additionally, public actors are concerned with matters such as the stability of roads and bridges, and how they are affected by the geological features of the land. As the primary provider of such information in the State of Indiana, the IGS plays a direct role in assisting the aforementioned

[50] Interview with Public Health professional. March, 2017.

agencies with this work. As discussed later in this report, obtaining this information from other sources would come at a substantial cost to state and local agencies. Another interview subject elaborated on how having cheap or freely available information can be a boon to small towns and communities in Indiana:

> *"I am glad the service exists and that [the IGS is] there to support the smaller cities and towns I work for as they do not have large operating budgets and the necessity for grant funds is imperative to better their communities. By providing this service free of charge, you are helping these communities to accomplish their goals."* [51]

In addition to assisting government agencies save money, mitigating public health risks, and collaborating with industry, the IGS provides valuable support through its outreach programs. For instance, one of its most valued and largest outreach programs to the general public is the Quake Cottage Program, a simulator that duplicates up to a 7.0 magnitude earthquake. The IGS partners with the Indiana Department of Homeland Security to educate the public on earthquake preparedness. Indiana sits on a fault line and is susceptible to earthquakes, potentially large in magnitude. This program is very unique to the state as there are only three other similar earthquake simulators in the United States.

> *"The Quake cottage program is our most valued educational resource. There are only three other quake simulators in the US so we are very unique to have it. We have something that no one else in central US or barely anyone in the US even has. It is a pretty important resource and we are going to take it out of the state this year, to some neighboring states to teach them about earthquakes. We reach thousands of people with this program, in the 5 years it has been run has reached almost 9000 people."* [52]

Not only is the IGS's earthquake preparedness valuable, but if an earthquake occurs in Indiana, the IGS is part of the emergency response team. The IGS is the only organization in the state that can indicate what occurs beneath the ground for earthquakes, which can save substantial resources in the event of an earthquake. It is impossible to estimate even a range of the value for these services considering a powerful earthquake has not occurred in modern history, but the benefits of this function of the IGS affects all residents and organizations in the state.

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51 Interview with a professional from a firm engaged in technical and scientific consulting. March, 2017.
52 Polly Sturgeon, Education and Outreach Coordinator for the IGS. February, 2017.

C. Industry

Over the past thirty years, the rock and limestone industry -- one of the major contributors to the state economy -- has been largely developed with the support of the IGS. It is not an exaggeration to state that the IGS plays a fundamental role in the natural resource industry.

The private sector makes extensive use of IGS information for an assortment of purposes. The transaction log data provided by the IGS indicates about half of their user base to be private industry, but only one-third of the responses to the IGS User Survey came from this group.[53] Examples of industries that utilize IGS extensively include: oil and gas, coal and other mining, environmental and other technical consulting firms, and insurance companies. Based on the user survey, over one-fifth of respondents representing private industry reported utilizing IGS information for the following activities displayed in Table 3 (right).

Table 3: Private Sector Uses

Top Uses: Private Industry
Groundwater and surface water
Roads/Highways
NEPA process
Oil and Gas
Clean Water Act
Transportation
Karst (sinkholes, drainages)
RCRA
Safe Drinking Water Act
Land acquisitions
Buildings and foundation
Railroads

Private actors mainly utilize the IGS to increase their knowledge about Indiana geology as it relates to their company's mission and projects. This can be further broken down into two top uses: knowledge for resource extraction activities, and for the development of land. Resource extraction companies trust the IGS to provide accurate information, which can incentivize outside companies to pursue projects within Indiana. By providing accurate information regarding natural resources, and by making this information easily accessible, the IGS has proven to be an irreplaceable resource to the business community. According to one of the interview subjects:

> *"IGS serves a neutral resource for businesses and organizations. It provides something that's credible and believable. It protects the credibility of what the state has to offer. Most companies do not have a staff of researchers on hand to confirm what natural resources are in states. The IGS is trusted by businesses to provide accurate information, which leads to businesses coming to the state."*

[54]

Additionally, the IGS prevents organizations from starting projects that could be costly to conduct or impossible to finish. The IGS can also prevent ill-advised economic development in

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53 This result indicates that the IGS User Survey possibly under sampled the private sector. Further discussion of this is located in Appendix B.

54 Interview with a high level representative with a large-sized corporation. March, 2017.

areas that may not have the geological conditions that allow organizations to thrive, such as access to water and stable ground for construction. One private sector interview subject from the civil engineering industry provided our team with additional detail on how the IGS can prevent costly mistakes from occurring during project work:

> *"I once had a project in Madison County, and we were unaware of the gas lines, or some old and abandoned gas wells along the road project we were going to do. Part of the job was to coordinate with them. They actually alerted us about the fact that there were gas wells there. Had we not known that, we would have started construction and come across those wells. It would have cost a lot of money if we didn't deal with them in advance. They saved us a lot of money in that particular case."* [55]

In some instances, the private sector also benefits from IGS outreach activities, which are discussed further later in this section. One interview subject explained how their association benefits from IGS outreach, stating:

> *"We do consider IGS a valuable partner with us. They are valuable for mineral researches and mapping, but also, they have been a great partner on education and outreach, for people to understand why we mine products, and how they are mined, and how valuable they are to the business and consumers of Indiana. We value both sides of IGS."* [56]

D. Research

Academic faculty and researchers from every major university in Indiana utilize the information and tools created and disseminated by the IGS for their work. Often, this research is done by academic geologists, and can be similar in nature to the work done by the IGS. In this way, the upfront work done by the IGS to make information available to researchers is channeled into increased knowledge regarding Indiana's resources.

Table 4: Academic Uses

Top Uses – Academic Users
Groundwater and surface water
Karst (sinkholes, drainages)
Industrial minerals (limestone, sand/gravel, clay)
Earthquakes
Oil and Gas

[55] Interview with subject from the Civil Engineering Industry. March, 2017.
[56] A representative from a private industry in Indiana (Indiana Mineral Aggregates Association). March, 2017.

Over one-fifth of respondents representing academic institutions reported utilizing IGS information for the activities listed in Table 4 above. While these uses appear quite similar to the uses listed for private industry and government users, the final purpose of this utilization differs. While the focus of this study is primarily on the value that the IGS creates through its contributions to the private and government sectors, it is important to note the way that the IGS feeds into the creation of knowledge throughout the state.

Research contribution, an important component of the value of the IGS, is difficult to capture quantitatively. Since the IGS produces public research on geological issues in Indiana, its spillover effects go beyond the IGS's direct engagement in economic and social domains. This indirectly contributes to innovations and changes in geological industry development, and ultimately leads to greater macroeconomic growth.

Much of the IGS's research serves the practical needs of the state and industries, which channels into their products and services, such as mapping and consulting; this is partially captured through our survey of state agencies, industry clients, and individual users. However, a portion of the IGS's research does not channel directly into their products and services and is not captured in our survey. A systematic analysis of the IGS's academic research is not feasible to quantify the value of their research. We cannot estimate what portion of their research is captured in our valuation of the IGS, but we can discuss some of this research's impact.

1. The IGS as a University-Based Research Organization

Located on the campus of Indiana University (IU), the IGS carries some university functions, and engages in many interactions with the university and students. The IGS can carry out similar functions as an academic department, such as providing courses and research opportunities to students. IGS staff teach courses for naturalist certification. They also provide instruction through internship opportunities for graduate students to conduct geology research. Currently about 13 graduate students work as interns or research assistants at the IGS.[57]

As an educational and research organization within the university, the value of the IGS includes adding to the stock of knowledge with its basic and long-term research results and developing human capital for the future geological workforce. Research results of the IGS provide basic information of the subsurface geology conditions and resources from past to present. This fundamental research supports decision making, allows new products and services to be created and provides the basis for future analyses and projections. Training students is also an essential part of its contribution. The IGS involves graduates with geology research and real world

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[57] Capstone Interview, Personal interview by Ashwood, C. & Geng, S. (2017, March 31); Round-table Discussion, Conducted by Ashwood, C., Geng, S., & Olorunnipa, I. (2017, February 28).

projects and prepares them for entry into professional and academic fields. This may also benefit industries by supplying well-trained and skilled graduates.

2. The IGS as a Practical Research Organization

The IGS's function as an academic department is limited to the proportion of credit hours provided and the number of students guided. It contributes only a small portion in the scope of the entire university. The IGS's research value is mostly reflected in its application of research results, direct delivery of products and services, and cumulative impacts for industry advances. A large part of the research goes into the maps produced by the IGS, as well as the consulting services for clients. With the products and services built upon research results, the IGS is able to provide direct support to various stakeholders for geology related activities. For example, geological advice and instruction is provided to industry clients through which commercial benefits may be enhanced and financial costs avoided. These are the benefits captured using our quantitative methods.

Due to methodological limitations and the wide variety of IGS services, some of the value of the IGS is difficult or even impossible to quantify, such as contributions of its education outreach function and academic research. Since the IGS contributes its staff mainly to practical and technical issues, especially in industry sectors like coal, stone, and oil and gas, some might neglect or underestimate its value in research and education outreach. An official at a major university in Indiana, stating:

> *"They [IGS staff] have this practical component that they have to fulfill. And they still do research beyond that, so the research part is what you will find in a geology department. They provide that research connection, as well as what I call 'public facing direction' to people."* [58]

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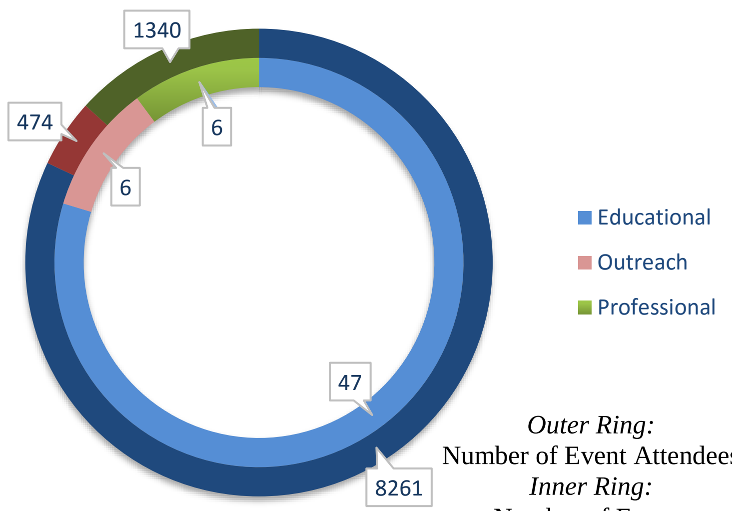
[58] Interview with an official at a major academic institution in Indiana. March, 2017.

E. The Public, Educational Outreach

Figure J: Number of Events and Attendees



In addition to the use of IGS information for business, safety, or environmental purposes, the IGS provides educational outreach throughout the state of Indiana. As mentioned, much of this educational value is not encompassed in our survey. However, the scope of the education programs is vast, and comprises beneficiaries such as the general public, educational institutions, government, state and private agencies.

Through education and outreach, the IGS serves an important role to Indiana. Although the IGS is not primarily an educational institution, its outreach and partnerships are highly valued, as they are aimed at providing information, educating the public, and creating awareness about the history and uniqueness of the geology and natural resources of Indiana. In 2016, outreach and educational programs served over 10,000 people. The IGS remains dedicated and committed to disseminating information and increasing knowledge of the resources and geology of the state through its education outreach and events. We interviewed the IGS's education outreach coordinator, Polly Sturgeon, to gauge the variety of services the IGS provides the public. While many of the users of the IGS's education and outreach were from the general public, our conversations with various stakeholders also touched on the ways that the IGS's educational mission is used by a variety of stakeholders.

The IGS's contribution to education cannot be solely explained through the sectors described above. Much of its contribution to the state can be seen as benefiting the public at large, through its contribution to science education. Among the general public, the IGS's educational contributions mainly take the form of general tours, and partnerships with organizations for outreach events and exhibitions. Collaboration on outreach programs such as *WeDigBio* caters to researchers across the globe, as it allows for the provision and accessibility of paleontologist's collection and photos of fossils through a worldwide database. The IGS also serves as a storehouse of knowledge, housing archives of core geologic samples valued at up to $21 million, which is available to the public. This core sampling translates into the IGS's maps, but the collection also produces value in its existence as a public resource.

Within the educational sector, the IGS's contributions benefit both Indiana University and K-12 education. At Indiana University, the survey conducts geological walking tours around the campus approximately 6 times a year to increase awareness of the unique limestone structures and geology of Indiana. Several events are held that are especially beneficial to IU students, and some are accessible to the general public, such as *Fossil Day*, held by the IGS on campus. In addition, the IGS conducts masters-level naturalist classes for naturalist certification at the university. According to an interview subject from a university in Indiana,

> *"The IGS serves a vital service not only as a repository for important information but as a source of expertise in a broad range of geology. I was particularly impressed by the active role the IGS plays in science education. Knowledge in this area is increasingly important as most of society is losing connections with the realities of the natural world."* [59]

As mentioned, the survey also provides support for Indiana's K-12 system. The IGS regularly provides up to 20 lesson plans, updated to state standards, for Indiana K-12 teachers. In order to continually fulfill its mission of knowledge creation, the IGS conducts regular classroom visits, holds Boy and Girl Scout events, and creates a library program for elementary school students. Outreach also helps to foster interest among children in the field of science. The IGS also holds or participates in several general public events such as *Geofest*, which is its largest event by participation, and holds the biannual *Hoosier Association of Science Teachers Inc.* conference, a geology conference for Indiana K-12 teachers.

Finally, the IGS is part of the Alliance of Bloomington Museums and creates a museum guide broken down into categories of history and science. The IGS also improves knowledge of resources in Indiana through the creation and regular updates of state park geology guides, self-service guides to limestone sites in Monroe and Lawrence counties, and its limestone photo collection.

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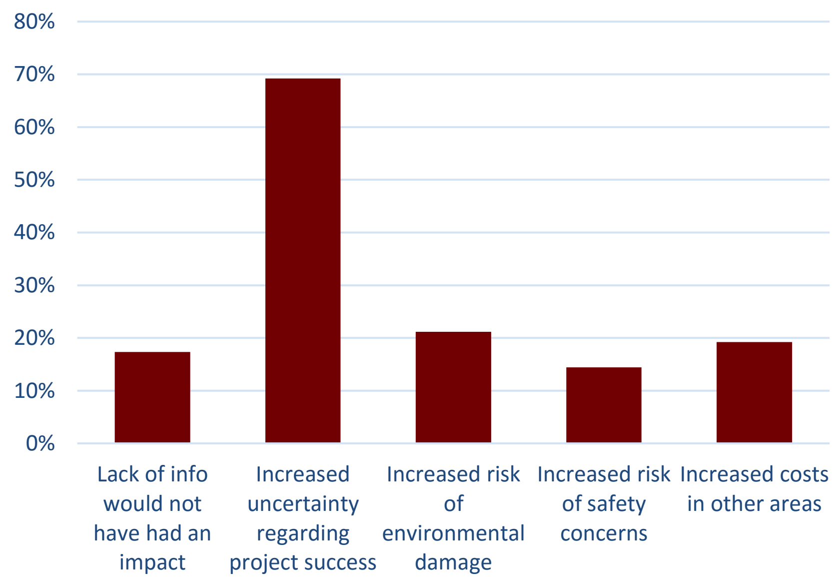
[59] Interview a representative from a major academic institution in Indiana. March, 2017.

IV. Economic Impact

A. Cost Savings for Users of IGS Information

The Indiana Geological Survey distributes information and data at a steep discount or entirely for free to members of the public. In total, the IGS receives about $25,000 in annual fees from these services. In the absence of this public service, private, government, and academic actors would need to acquire these materials from another source (e.g., paying a consultant, doing field work, or from some other source). Consequently, one of the primary sources of value examined in this report is the cost savings generated on behalf of Indiana stakeholders who use IGS resources. These averted costs vary based on the type of actor. For some, not being able to use the IGS may be a minor inconvenience; for others, it would cause substantially higher project costs, lower return on investment, and limits on profitability and efficiency.

Figure K: Consequence of Proceeding without Information



Not all who receive IGS information would necessarily replace it with information from a more expensive source. This should not imply that the information lacks value. Instead, it illustrates how industry and government actors would be willing to accept increased risks related to their projects rather than pay substantially more for geological information. Approximately one-third of the respondents of the IGS User Survey indicated that they would have proceeded with their work without IGS information if it were not available. A large majority of this set of respondents elaborated that the lack of information would lead to increased risks of environmental damage, safety concerns, or a general increased uncertainty regarding project success.

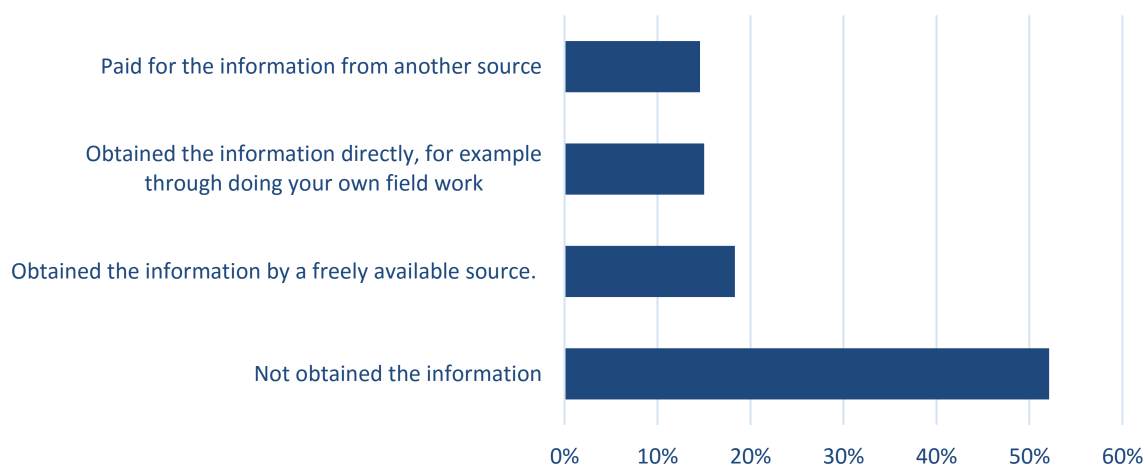
While increased environmental risk and increased safety concerns can be difficult to quantify, what is clear is that users of IGS information would be faced with increased costs if the IGS ceased to exist. Thus, we valued these services on a per-use basis. This method examines the “replacement cost” of IGS information, putting a value on each use of IGS information.

Determining what constitutes a "use" is not necessarily the most straightforward task. In this instance, we split uses into two categories: information that is obtained through direct request (e.g. email, phone call, letter, etc.) to the IGS, and information that is gained by visiting one of the resources on the IGS website, such as IndianaMap. The replacement costs for these types of information are different, as information requests are more likely to be chargeable, and require a higher degree of staff time to prepare than web-accessed information. Additionally, users may navigate to the website to obtain minor pieces of information, while obtaining complex or large amounts of information is more likely to require a data request to the IGS.

1. Requested Information

IGS users were first asked to identify and classify the last piece of information they *requested* from the IGS. In order for us to gain a better perspective of typical IGS service requests, the IGS User Survey asked respondents to identify the most recent time they contacted the IGS. Asking for information about the most recent request in particular helped reduce survey bias by preventing respondents from thinking about the most expensive or demanding service requested in recent memory. In this way, the survey also attempted to isolate the value of one piece of information. Respondents were then asked what they would do if the IGS was unable to provide them with this piece of information. Figure L shows the response breakdown.

Figure L: Action if the IGS Could Not Provide Information?



Notably, many respondents would not have obtained the information from another source. Reasons for this include users not believing there is any alternative to using the IGS, or that obtaining it from another source would be prohibitively costly. One private sector interview subject indicated that finding a substitute would be very challenging;

> *"We would either go to a private consultant or contact USGS. I have always been working with the IGS; I don't know where to get the information or expertise elsewhere."*

[60]

Many respondents to the IGS User Survey responded similarly; since they had become so accustomed to utilizing the IGS, and they did not have an alternative source of information in mind, they responded that they would not replace the information.

Geological information may not be replaced because it is because it would be prohibitively costly. An interview subject from the field of public health indicated that they lack the budget necessary to hire a consultant that could supply them with the same information that they routinely receive from the IGS. Because this group would not have obtained the information from another source, we coded their response to reflect zero value of IGS information so that our valuations would lean conservative. However, a major assumption made in this analysis is that these people would be *able* to replace IGS information. If they were unable to find and afford a replacement, actual economic losses would probably be greater.

The 50 percent of respondents that would have replaced the information in some capacity were then asked about what they would expect, or be willing, to pay for such information. These respondents reported an average replacement cost of **$3,066**.[61] The individual estimates varied widely, ranging from tens to thousands of dollars. It is important to reiterate that this figure does not represent the total value that each user derives from the IGS in either a total or annual basis. Instead, it represents how the average user values their *most recent* information request from the IGS. To put it another way, the average user would expect to pay $3,066 to a private consultant to obtain whatever information the IGS most recently provided them.

Based on the records kept by the IGS, there are an average of 1,743 service requests per year (over the past five years). While a request might contain more than one piece of information, for the purposes of this report, each transaction was counted as one piece of information. However, this figure is not perfect. Some transactions are admittedly never recorded in the log, while some of the recorded items could be as simple as a phone call asking how a web-site feature is used. That said, the transaction history gives us the best possible estimate of the volume of requests that the IGS handles annually. Based on this annual request volume and the estimate obtained through the survey, we estimate that these transactions represent an annual value of **$5.34 million** to those who rely on IGS information.

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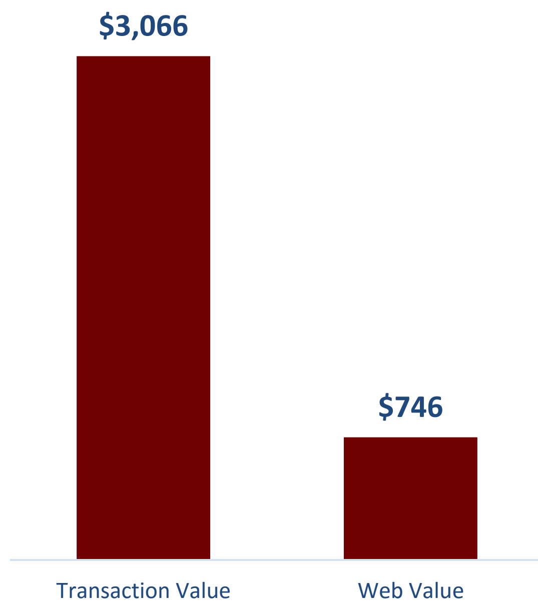
60 Interview conducted March, 2017.

61 For a more detailed description of how responses were analyzed, see appendix B.

2. Web-Based Information

Figure M: Per-Use Valuations



While the IGS performs an average of 1,743 transactions a year, this number does not account for the number of individuals who access free services hosted by IGS web servers. Free services range from geological information on the website, geologic databases, and notably an interactive, customizable map with which users can compile their own map of relevant information. Because this information is accessed differently, the IGS User Survey asked respondents to put a separate value on each use of this information. Respondents were once again asked to identify the last time they had used one of these resources, and were then asked to estimate what they would expect to pay if they had to obtain it from a different source. Perhaps because of the nature of the information (received freely with little time investment), respondents provided much lower values of what each use of this information was worth to them; the average per-use valuation came to **$746.** We believe this reflects the varied usage of the IGS website. Some users will utilize it to simply look something up, while others will use the web-tools extensively for project planning.

While the web-based information may carry a lower per-use value, there are many more such uses than the transactional, contact-based uses described above. Based on the number of times respondents reported using IGS information per year, we estimate that identified users (those who have contacted the IGS in the past two years) account for over 6,000 web-uses per year. However, the identified users we surveyed only account for a portion of the total population of people who make use of IGS web-tools. Many users make frequent use of online maps and resources and never contact the IGS, meaning they are not accounted for in the 6,000-web use estimate. In order to evaluate the full population of users, website access data via Google Analytics provided by the IGS was evaluated.

The analysis of Google Analytics data described here focused solely on two of the most important tools supplied by the IGS; IndianaMap and the Petroleum Database Management System (PDMS). Our team chose to focus just on these tools to avoid potentially double counting users that accessed multiple online resources, which would skew our count of unique users. As opposed to counting unique IP addresses that accessed any part of the IGS website, our approach was more targeted toward identifying users more likely to be engaged in some form of development project. Google Analytics data show that these tools were accessed by 65,675 unique IP addresses in 2016.[62] Because users who access these tools may do so from multiple computers or web browsers, it is likely that some of these IPs should not be considered as unique users. Thus, we adjusted the figure by one-half, leaving an estimated 32,837 unique annual users of Indiana Map and PDMS.

Identified Users
(Contacted IGS)

- **6530** Website-Uses
- **1743** Requests (contacted IGS)

Web-Only Users
(Estimated from Google Analytics)

- **26,304** estimated unique users

The $746 replacement value derived from the survey was applied to the adjusted web-user total of 32,837, resulting in an estimated annual valuation of **$24.49 million.** This method conservatively assumes that each unique user only made use of these tools once per year. While this is in all likelihood not the case, assuming one use per user allows us to derive a lower bound estimate of the value provided through the website to these users. Another way to look at this is: what would users be willing to pay for these tools if they required an annual subscription fee? Because survey respondents indicated that they would be willing to pay $746 for the last piece of information they obtained from the website, we can conservatively assume that they would be willing to pay that amount to use it as an annual service. Total replacement cost then, including both the value of requested information and the value of information obtained via the web, is estimated at approximately $30 million as displayed in Table 5.

Table 5: Replacement Cost Valuation

Value of Requested information	$5,344,282
Value of information obtained from website	$24,489,848
Total Replacement Cost Value	$29,834,130

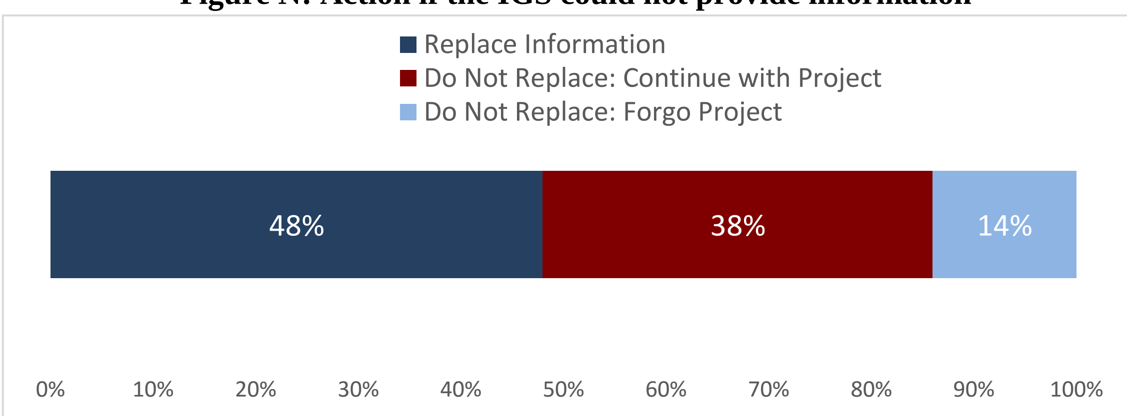
[62] See Appendix B for further explanation of this methodology

B. Foregone Projects in Absence of IGS Information & Data

While the above analysis assumed that all information provided by the IGS would be replaced by another source, there would of course be instances where this is not the case. Some projects would not be completed in the absence of these services; there would simply be no alternative to acquiring the information from the IGS, and the absence of that information would be a prohibitive challenge to project completion. It is helpful to consider this concept from the perspective of return on investment. For projects where the acquisition of geological information is critical, and obtaining it through field work or through a consultant would be costly, not being provided the information for free or very cheaply through the IGS could drive the return on investment below the necessary level to initiate the project. The tools provided by the IGS reduce the cost side of the equation for projects conducted by both the private sector and government agencies. By reducing these costs, some projects will inevitably become more realistic and attainable. The value of the projects at the margin—that is, the projects that would be lost without the IGS—was also captured through the IGS User Survey.

Through the IGS User Survey, respondents were split into two groups: those who said they would try to *replace* the last piece of information they receive from the IGS, and those who said they would have carried on *without* it. Half (52 percent) of the group said they would not have replaced the information. Among that half, some 28 percent of respondents further indicated that not having the information would have meant cancelling their project. Figure N describes this breakdown:

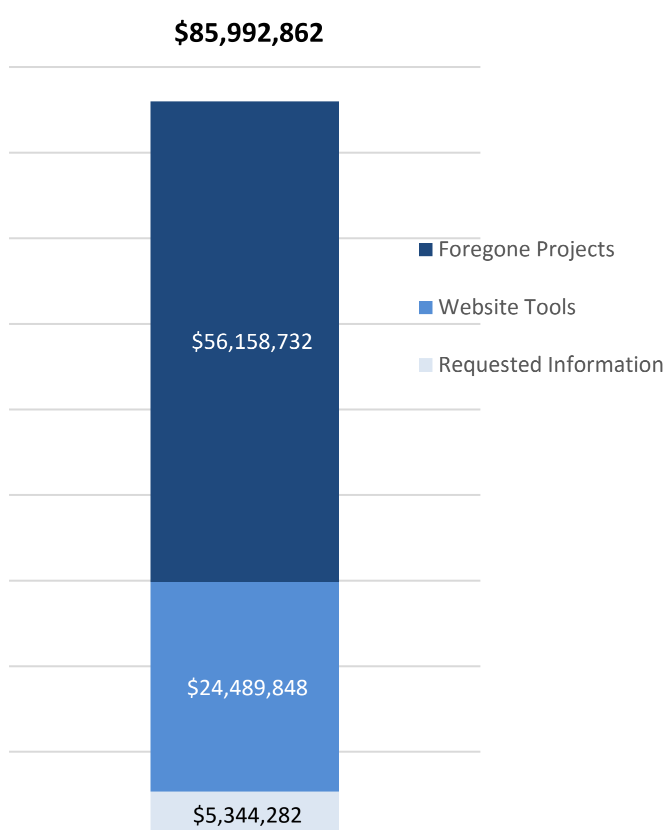
Figure N: Action if the IGS could not provide information



Overall, 14 percent of all survey respondents indicated that they would have foregone their last project that used IGS information in a scenario in which the IGS could not provide it. These respondents were then asked to identify the cost of that project. This was done to acquire a lower bound estimate of those projects' values; for example, if a project cost was $10,000, we can assume that the *value* of that project was expected to exceed that amount. Respondents reported an average project cost of $578,956.[63]

Based on IGS transaction records, an estimated 711 unique users contact the IGS to request information on an annual basis. Assuming that 14 percent of these users would have foregone a project without this support from the IGS, the we concluded that 97 projects would be foregone on an annual basis in the absence of the Indiana Geological Survey. Assuming that each of these projects would carry a value of $579,000 as estimated by the IGS User Survey, we estimate that annually **$56.16 million** worth of projects would not be carried out without the IGS. Similar to the cost savings estimate, this figure also conservatively leaves out all the users who solely rely on web-based information. While this withholds some value from the final estimate, it should be noted that there would certainly be additional projects that would go uncompleted by web-only users.

Figure O: Direct IGS Impact



Combined with the replacement cost value discussed earlier, we estimate that the IGS creates a direct economic impact of **$85.99 million** per year. This estimate combines additional costs that would be incurred by government agencies, private industry, and academic researchers if the IGS did not exist, in addition to the value of projects that would have to be foregone under the same scenario.

If anything, we believe this $86 million figure represents a lower-bound estimate of economic impacts. This is likely the case for several reasons. First, this analysis did not include all of the various tools available on the IGS website, and only focused on unique users who accessed IndianaMap and the PDMS. Second, the estimate of how many projects would be foregone was not extended to users who use only the website; it focused solely on known users who have contacted the IGS in the past two years. Additionally, the per-use value that was gathered from the IGS User Survey was substantially lower than values collected from a similar study on the Ohio Geological Survey by Kleinhenz and Associates. Asking users to place a value on something they are used to receiving for free or

63 To diminish the influence of an outlier, one reported valuation of $500 million was winsorized to $5 million for the calculation of this average.

cheaply is difficult, as imagining a counterfactual scenario in which the IGS does not exist can feel like a nebulous exercise. The IGS User Survey attempted to account for this by isolating users who said they would obtain the information from another source if they could not obtain it from the IGS. However, the nature of this type of survey likely resulted in a low estimate of what IGS information is actually worth to its users.

An additional reason why the $86 million figure may be a low-end estimate is that IGS research opens up opportunities for government and industry that would otherwise not exist. One interviewee noted that the "IGS provides citizens of Indiana crucial information about water resources, locations of old mines, and characterization of current and potential future resources."[64] This research increases the general knowledge regarding Indiana's natural resources, thereby creating project opportunities. While this is difficult to quantify, it would certainly contribute to our final estimate.

C. Secondary Benefits Associated with The IGS (Input-Output Model)

In addition to providing value through its services, research, and educational outreach, the Indiana Geological Survey contributes to the Indiana eonomy by spending money locally and supporting Indiana businesses through purchases. This additional value can be captured by utilizing an input-output model.

1. Definitions and Explanation of I-O Model

The input-output (I-O) model is one of the most popular methods for analyzing the economic contribution of projects and services at the sub-national level.[65] I-O models provide a snapshot of an economy by following transactions through backwards supply linkages as companies purchase capital and labor from other companies that also purchase capital and labor. Every expenditure an industry makes sets off a chain reaction of spending throughout the economy, contributing to increased demand and economic growth. The I-O model tracks initial and subsequent rounds of transactions, resulting in a measure of economic impact based on the sum total of spending that occurs within the economy of interest.

This spending can be captured by assessing three distinct sets of economic impacts: Direct, Indirect, and Induced.[66]

Direct Impact: The results of expenditures made by the industry of interest are described as a direct impact on the economy. For example, when the IGS purchases lab

64 Interview with industry representative. March, 2017.
65 Davis, H. C. (2014). Regional Economic Impact Analysis and Project Evaluation. *UBC Press.* P. 53.
66 Day, F., Alward, G., Olsen, D., & Thorvaldsen, J. (n.d.). Principles of impact analysis & IMPLAN applications. *Retrieved from* http://support.implan.com/index.php?view=download&alias=32-piaia-sample&category_slug=demo-1&option=com_docman&Itemid=1764.

supplies, the cost of the supplies represents a direct impact on the economy.

Indirect Impact: The results of inter-industry expenditures made through the backward supply chain linkages are identified as indirect impacts. For example, when the lab supply company purchases shipping materials to send IGS their product, these shipping purchases represent an indirect impact on the economy.

Induced Impact: The results of expenditures made by employees of the directly affected industry and employees of the industries among the backward linkages are identified as induced impacts. For example, when IGS employees purchase groceries, a portion of their purchase supports the employment of cashiers at the local grocery store. Employee purchases represent an indirect impact on the economy.

One of the most important features of I-O models is the geographic definition of the affected economy. This is because the model seeks to capture only the portion of each transaction that remains within the geographic boundary. At each supply linkage, a portion of the original expenditure either leaks out of the economic boundary or ceases to stimulate additional spending, through taxes, savings, profits, and imports. Because the IGS relies on a state appropriation for most of its funding, for our purposes we have identified the state of Indiana as the most appropriate geographic boundary within which to capture the economic impact of the IGS.[67]

a. Assumptions and Limitations

I-O models are based on a set of assumptions. The most significant assumption is that of "fixed direct purchase coefficients,"[68] or the assumption that industry spending patterns by proportion of industry are fixed over the period of the study. For example, we assume that if the IGS doubled its purchases of lab supplies, the industry manufacturing those supplies would continue to purchase inputs and produce supplies at its same historical proportion. Price changes, supply shocks, shifts in industry activities, or technology changes could render this assumption invalid. The remaining significant assumptions are linearity and homogeneity, or—together—the assumption that every input has a fixed proportional output among fixed sectors. This assumption does not allow the analyst to account for economies of scale or other non-linear economic functions. For example, the I-O model will not capture the change in input expenditures if an industry moves from purchasing at retail rates to wholesale rates. Finally, when calculating the induced impact, there is an assumption that household spending is also linear and homogenous.

Similar to the economic impact study of the Ohio Geological Survey by Kleinhenz and Associates, we make a distinction in our analysis by separating the economic contribution from economic impact.[69] The economic contribution represents the sum total of economic activity

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67 Ibid 65.
68 Davis, H. C. (2014). Regional Economic Impact Analysis and Project Evaluation. *UBC Press*. P. 62-64.
69 A Kleinhenz & Associates. (2011). An Economic Impact Analysis of the Ohio Geological Survey's Products and Services. *Kleinhenz & Associates.* P.4.

within Indiana that is made possible by IGS expenditures. For our purposes, the IGS's total economic contribution will be derived by incorporating all expenditures made by the IGS into the I-O model. In contrast, the IGS's total economic impact is derived by incorporating only those expenditures made possible by federal and other non-Indiana based revenue. This allows us to establish the economic activity in Indiana that occurs as a result of new money being injected into the economy.

We utilized IMPLAN, a well-known input-output software system, in order to conduct the input-output analysis of the IGS. Information provided by the IGS on fiscal year 2016 (FY16) expenditures grouped by object code were analyzed and grouped according to three-digit industry codes provided by the North American Industry Classification System (NAICS). Within IMPLAN, each industry code is associated with an indirect and induced economic multiplier that estimates the amount of money that remains within the geographic boundaries defined by the analysts. The list of expenditures by industry code can be found in Table 11 of Appendix D for each of the three models, along with the industry multipliers used for the calculation.

The following section illustrate the IGS's economic contribution and economic impact as described above. While these results reflect 2016 information, we assume this is relatively stable year-to-year, barring a major shift in industry or expenditure combination.

2. Economic Contribution to Indiana (based on all IGS expenditures)

The Indiana Geological Survey had a budget of approximately $3.5 million in FY16 (July 1, 2015 – June 30, 2016). Of that amount, about $3.1 million was attributed to salaries and related compensation, while the remaining $400,000 was attributed to supplies and operating expenditures. The resulting economic contribution to Indiana in terms of output, which represents the value of inputs to labor and supplies, was approximately $6.3 million. This implies an economic multiplier effect of approximately 1.8. Every $1 spent by the IGS results in a $1.80 contribution to the Indiana economy. This result is similar to the input-output estimate of the economic contribution of the Ohio Geological Survey completed by Kleinhenz and Associates; they also generated an estimated multiplier of 1.8.[70]

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[70] A Kleinhenz & Associates. (2011). An Economic Impact Analysis of the Ohio Geological Survey's Products and Services. *Kleinhenz & Associates*. P.15-16.

Table 6: Impact of IGS Expenditures

Estimated Economic Contribution	Output
Direct Effect	$ 3,561,377.00
Indirect Effect	$ 132,956.53
Induced Effect	$ 2,610,053.25
Total Output Effects	$ 6,304,386.78

3. Economic Impact (based on IGS expenditures sourced from non-Indiana revenues)

Of the Indiana Geological Survey's $3.5 million budget, approximately $417,000 is derived from contracts and grants originating outside of Indiana's borders. Expenditures made as a result of these contracts and grants represent impacts to the Indiana economy as defined above. This represents money that has been injected into the Indiana Economy as a direct result of the IGS's efforts. If IGS did not exist, this money would not likely have entered the state economy. As seen below, the estimated total impact of these expenditures amounts to approximately $750,000.

Table 7: Impact of IGS Expenditures (Non-Indiana Revenues)

Estimated Economic Contribution	Output
Direct Effect	$ 416,593.72
Indirect Effect	$ 41,235.03
Induced Effect	$ 287,050.86
Total Output Effects	$ 744,879.60

4. Shadow Pricing

The input-output model provides a snapshot of the economy based on market transactions. However, based on the results of the IGS User Survey, we believe market transactions do not capture the IGS's full contribution to the Indiana economy. While the IGS User Survey indicates a total cost savings of $5,344,282 from requested information and $24,489,848 from web-based information, the IGS only received $25,000 in client revenue for these services, representing significant savings on the part of IGS clients.

In order to capture the economic ripple effect resulting from IGS clients' cost savings, we used the IGS User Survey results for replacement cost to identify the shadow price (market cost plus consumer surplus) of research information provided by the IGS to industry clients. We then added the difference between the shadow price and actual client services revenue received by the IGS during FY16 to the I-O model, as if the IGS made a direct monetary exchange (payment) to the client industries. While the value of foregone projects estimated by the IGS User Survey can be attributed to the IGS's provision of information, the decision to forego projects is ultimately marginal. Because IMPLAN is based on the assumption of linearity, we only utilize the value of the cost savings from transactions of services, both offline and digital.

By adding these cost savings as direct monetary exchanges into the model, we made the assumption that the money saved by clients from paying a market cost below the true economic value would ultimately be spent on projects proportional to their current spending. Taken inversely, we assume that client spending would have decreased proportionately had they paid for the full economic value of IGS information. We also assume that client activities would remain the same in the face of increased information costs through the IGS.

After adding the $29 million to the economic contribution model, we arrive at a total of $33,395,507 as the direct economic effects of the IGS. Plugging this value into the model, we find that the total estimated output effect to the Indiana economy is $57.7 million. This economic contribution represents a significant boon to the state economy, far exceeding the $2.8 million appropriation from the State of Indiana.

Table 8: Total Economic Contribution

Estimated Economic Contribution	Output
Direct Effect	$ 33,395,507.00
Indirect Effect	$ 7,607,217.95
Induced Effect	$ 16,845,233.52
Total Output Effects	$ 57,847,958.47

IV. CONCLUSIONS

This report documents the ways in which Indiana Geological Survey provides value to the state. The IGS is a critical tool for public, private, and academic actors throughout Indiana. The IGS also produces research, catalogs materials, and furthers knowledge regarding natural materials. This work is all channeled into digital and non-digital tools and services, which are utilized by thousands of individuals across the state. In addition to supplying better information to government agencies and private companies, the IGS engages in large-scale educational outreach programs that help to educate children and adults about Indiana's resources and economy.

The results show substantial economic value to Indiana. Without the IGS, stakeholders across all sectors would lose out on at least $29 million in geological information that they currently receive each year. In addition, $56 million worth of projects would be foregone, either because obtaining replacement information would be impossible or prohibitively expensive. In addition to these direct impacts, without the IGS, $24 million in additional indirect and induced impacts would be lost as the result of decreased economic activity. In total, we estimate that **$110 million** in economic value is attributable to the work done by the IGS. This likely understates the actual value, due to conservative assumptions made in our analysis. The most important of these reasons is that, in the absence of the IGS, it is unlikely that there would be any resource capable of preventing the costly mistakes that would seriously burden government and private actors. Especially impacted would be companies involved in resource extraction, land acquisition, and environmental engineering, as well as major state agencies such as the Departments of Environmental Management and Transportation. Tables 9 and 10 (below) show the various valuations estimated by this report, as well as those established by previous studies on the value of geological information.

Table 9: Calculated Benefits

Benefit	**Estimated Value**
Cost Savings from Requested Information	$5.34 million
Cost Savings from Website Information	$24.49 million
Value of (otherwise) Foregone Projects	$56.16 million
Indirect and Induced Economic Output	$24.45 million
Total calculated benefits:	**$110.44 million**

Table 10: Benefits Estimated From Other Studies

Benefit	Estimated Value
Risk Mitigation and Cost Minimizing Regulation	$500 million to $1 billion, estimated net benefit to California, in report by Bernknopf and Shapiro (2015)[71]
Improved decision making from moderate resolution land imagery (MRLI)	$38 billion, estimated net present benefit to Iowa, in report by Bernknopf and Shapiro (2015)[72]
Improved decision making from GIS technology implementation	$2.9 million, estimated net present value to Illinois, in report by Hall, Kim and Darter (2000)[73]
Public investment in research	200-800 percent return on investment, estimated by Georghiou (2015)[74]

This report has also shown the difficulty inherent in quantifying the public dissemination of information. Without reliable information regarding the conditions under the ground, costly mistakes, environmental degradation, and major safety concerns would quickly arise throughout the state. These problems are avoided in part through the valuable work conducted by the IGS. The IGS itself is a public good; the private sector would have no incentive to produce and freely publish this type of information, as there would be little to no profit motive inherent in such activity. This report has attempted to value this public good by predicting what would happen if the IGS were to no longer exist.

In addition to the quantitative valuation attempts, we spoke directly with IGS staff members and representatives from every sector, in an attempt to contextualize the importance of the geological survey. These interviews revealed how valuable a service the Indiana Geological Survey has proven to be. The IGS helps government agencies avoid costs and better protect the public from environmental concerns. Through disseminating knowledge about natural resources, the IGS opens up additional opportunities for research exploration and land development activities for industry. Academics use IGS information to further their own research, contributing to the body of knowledge available regarding Indiana's resources. Finally, interviews exposed the role that the IGS plays in educating the public and Indiana schoolchildren about science, resources, and Indiana's economy.

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71 Bernknopf, R.; Shapiro, C. "Economic Assessment of the Use Value of Geospatial Information." ISPRS Int. J. Geo-Inf. 2015, 4, 1142-1165.

72 Bernknopf, R.; Shapiro, C. "Economic Assessment of the Use Value of Geospatial Information." ISPRS Int. J. Geo-Inf. 2015, 4, 1142-1165.

73 James Hall, Tschangho Kim, and Darter, Michael, 2000, Transportation Research Record: Journal of the Transportation Research Board. 1719:, 219-226.

74 Georghiou, L. (2015), Value of Research. Public paper of Research, Innovation and Science Policy Experts (RISE). Retrieved from https://ec.europa.eu/research/innovation-union/pdf/expert-groups/rise/georghiou-value_research.pdf.

The IGS has fulfilled a vital role in Indiana since its inception. Going forward, its mission and activities must adapt to meet the ever-changing needs of the State. This will include efforts to assess water resource availability, and adding resources to assess long-term monitoring of water quality and quantity. This shift will bring different staffing needs, and will require the IGS to expend significant resources in additional research, mapping, and outreach. While the nature of the IGS's work will continue to change, its economic impact on Indiana will continue to be substantial.

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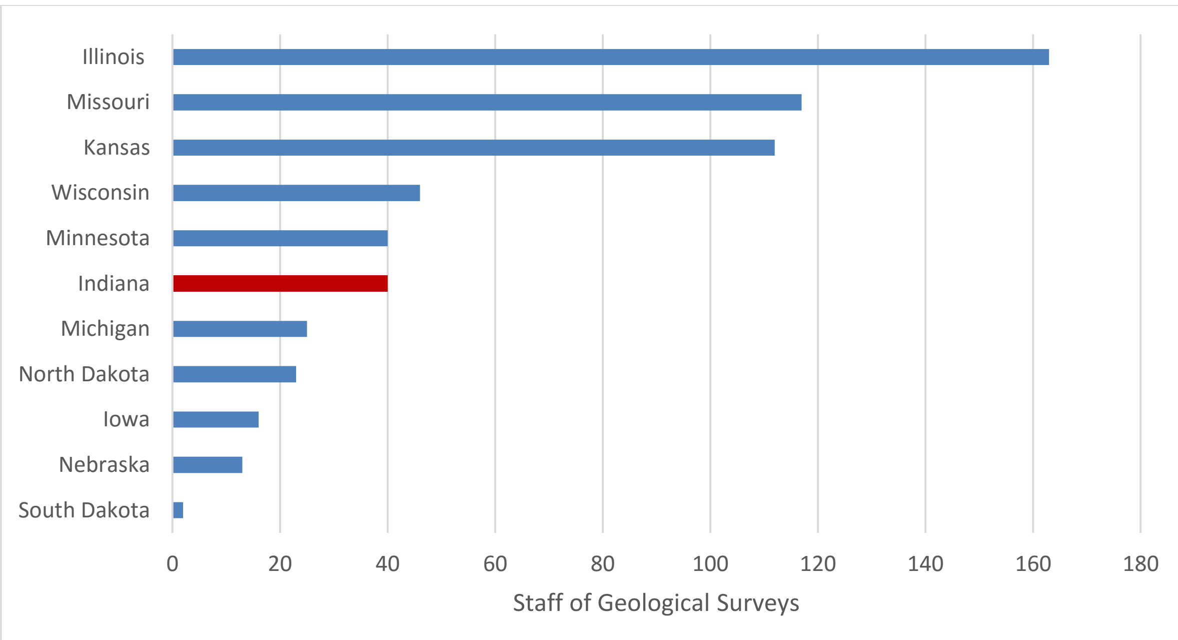
Appendix A: Geological Survey Comparison

In order to provide context to the challenges facing the IGS, the services, staff, expenditure, and appropriations of various geologic service organizations through the United States were analyzed. Specifically, the section below focuses on a regional analysis of Midwestern states. From this comparison we see that the IGS is significantly smaller than surrounding states, has slight more licensed geologist than average, and an average amount of funding from the state.

To identify the number of staff for each state geological survey or organization, the primary sources of information were geological survey websites. When information was unavailable from the survey websites, the information was compiled from the Association of American State Geologist (AASG) webpage. However, there are still seven state geological surveys for which recent staffing information could not be found: Georgia, Montana, New Hampshire, North Carolina, Ohio, Pennsylvania, and West Virginia. Figure P depicts how the size of the IGS is comparable to the other geological surveys in midwestern states.

Figure P: Numbers of Total Staff across Midwestern States[75]



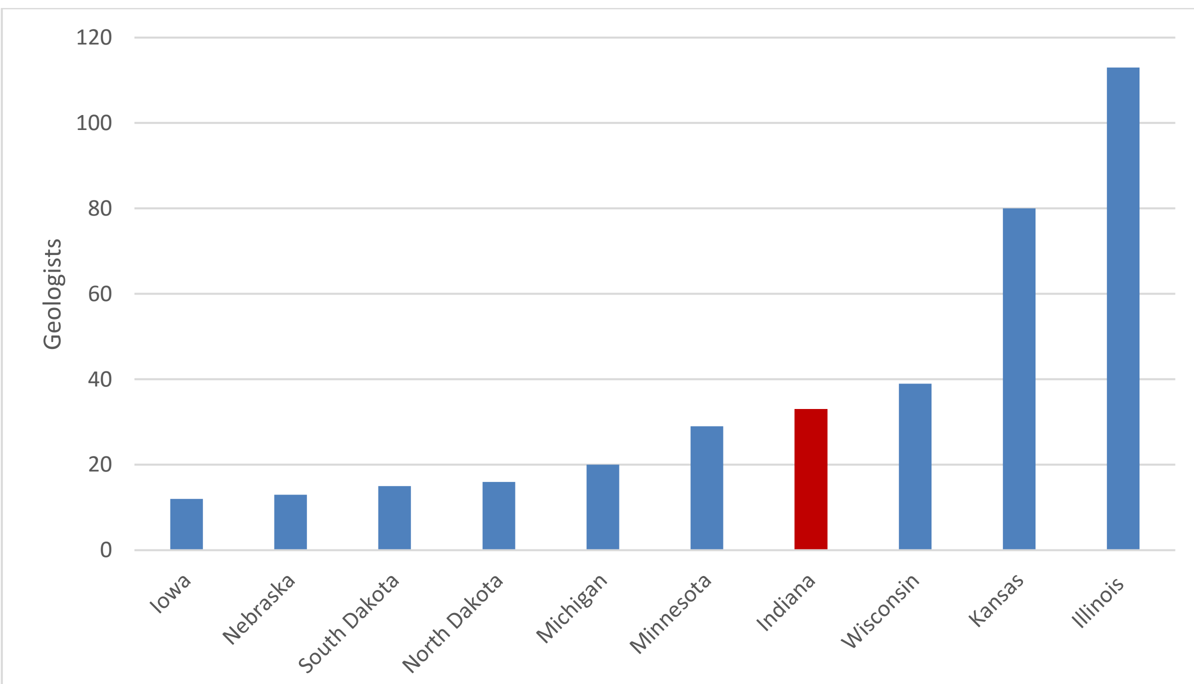
Compared to the other geological surveys in Midwestern states, The IGS's size is notably smaller than that of Illinois, Kansas, and Missouri, and a bit lower than Wisconsin's. The average size of geological surveys in terms of total staff is 54. The IGS is approximately average in size compared to neighboring surveys.

75 Association of American State Geologists (2017). "State Geological Surveys." Retrieved from http://www.stategeologists.org/surveys.php.

Number of Geologists

Identifying the numbers of geologists is more challenging than counting total staff. Websites of geological surveys do not clearly specify between geologists, administrative staff, and geologists who may play an administrative role. In addition, geological surveys that are part of a university have staff members who are also faculty members, raising the question of how to count them. To address this issue, we applied a decision rule to identify geologists: as long as the person in concern works on geological tasks, the staff member was counted as a geologist. We acknowledge that this identification is subjective and based on our own justification. Figure Q compares the IGS to other Midwestern states in terms of geologists employed. We find that the geological survey with the highest number of geologists is Illinois with 113 geologists. On average (excluding Illinois), a typical geological survey has 28 geologists, while the IGS is slightly higher at 33.

Figure Q: The Number of Geologists across State Geological Surveys – Midwest States[76]



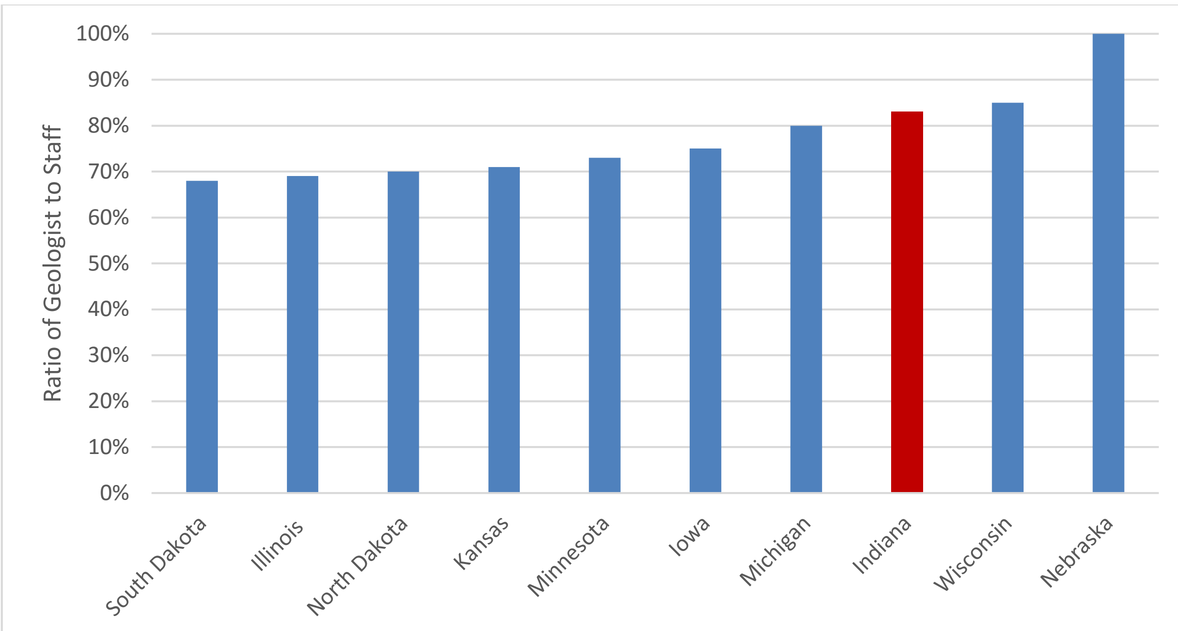
Ratio of Geologists to Staff

When evaluating the number of geologists to the number of staff as a percentage (Figure 8), Connecticut, Nebraska, New York, Vermont and Virginia are staffed entirely by geologists, and

76 Ibid 75.

Alabama has the lowest geologist-to-staff ratio at 53 percent. On average, a typical geological survey sees 80.51 percent of its staff as geologists; for the IGS, this figure is 82.5 percent. As Figure R shows, the percentage of geologists in the IGS is above the average percentage in the Midwest.

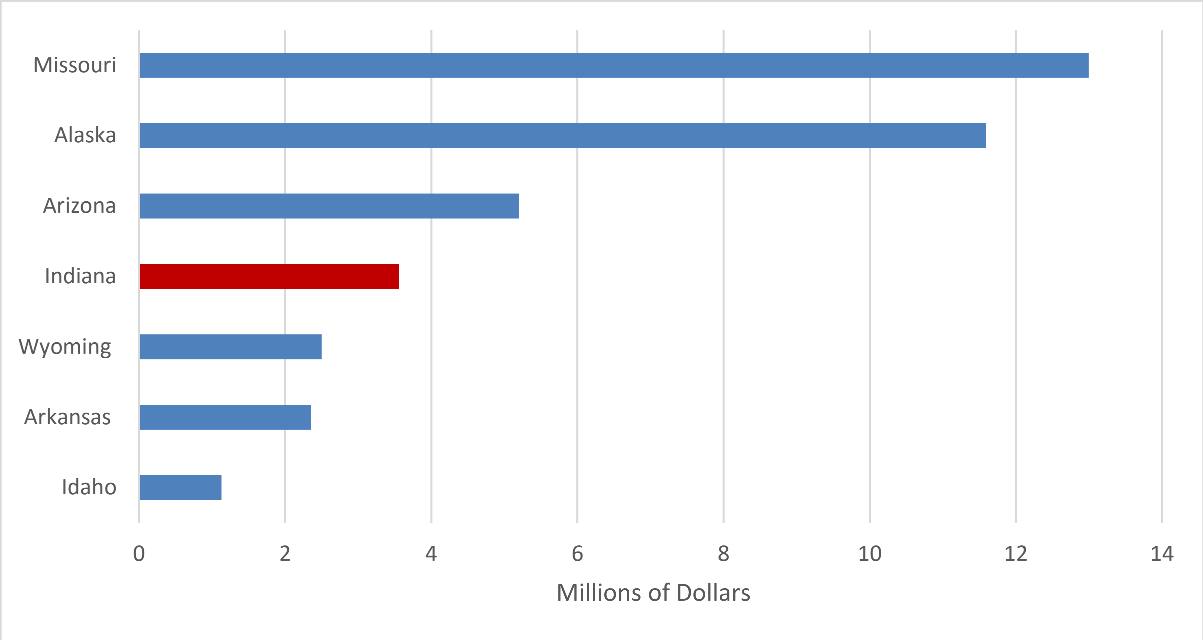
Figure R: Percentage of Geologists across State Geological Surveys – Midwestern States



Total Funding

Finally, it is necessary to review the total funding of the IGS, and how it compares to other geological surveys. Given the fact that many geological surveys lack publicly accessible financial information, the comparisons we made only included those geological surveys for which publicly available funding information could be found. The financial information of the geological surveys are found from various sources (please see Appendix 1). Figure S below illustrates the total funding in 2016.

Figure S: Total Funding for Available Geological Surveys



Note that in Figure S, we use the term “total funding,” meaning that this is the total amount that a geological survey receives in a fiscal year, not only from state funds, but also from additional resources. Although geological surveys can be funded from various sources, they are traditionally funded through state appropriation. When comparing the size of the IGS (40 staff members) and the total annual funds ($3.56 million) to other states, the IGS is considerablely lower.

Comparison Tables

Publicly Available State Geological Survey Funding Information		
State	Total Funding in 2016 ($ millions)	Source for Total Funding
Alaska	11.59	http://www.stategeologists.org/tmp/Journal2016.pdf
Arizona	5.2	http://repository.azgs.az.gov/sites/default/files/dlio/files/nid1666/2015-annual-report-skm-2016-01-07web.pdf
Arkansas	2.35	http://www.dfa.arkansas.gov/offices/budget/budgetRequests/0420_geological_survey.pdf
Idaho	1.13	http://www.idahogeology.org/uploads/Annual_report/AnnualReport_IGS_FY2016.pdf
Indiana	3.56	IGS Income Report (2016)
Missouri	13	http://www.stategeologists.org/tmp/Journal2016.pdf
Wyoming	2.5	http://www.wsgs.wyo.gov/docs/wsgs-annual-report-fy16.pdf

Staffing Levels by State				
Alabama	79		Mississippi	25
Alaska	39		Missouri	117
Arizona	17		Nebraska	13
Arkansas	29		Nevada	26
California	120		New Jersey	67
Colorado	19		New Mexico	91
Connecticut	9		New York	4
Delaware	20		North Dakota	23
Florida	32		Oklahoma	38
Idaho	12		Oregon	37
Illinois	163		Rhode Island	12
Indiana	40		South Carolina	20
Iowa	16		South Dakota	22
Kansas	112		Tennessee	14
Kentucky	70		Texas	198
Louisiana	18		Utah	69
Maine	11		Vermont	3
Maryland	29		Virginia	8
Massachusetts	40		Washington	33
Michigan	25		Wisconsin	46
Minnesota	40		Wyoming	21

[77]

[77] Excluded states did not have readily available or public information on the survey website or from the AASG.

APPENDIX B: IGS USER SURVEY

Purpose and Scope

In order to evaluate the broad range of clients and uses of IGS services, the Capstone Class designed, implemented, and analyzed a survey of IGS service users. The survey contacts were compiled by the IGS from contact logs of 2015 and 2016 requests for information, services, or recommendations. These requests represent a sample of IGS service users from all sectors of the marketplace. Not all contacts are recorded by the IGS, but the logs contain the best available sample of IGS users.

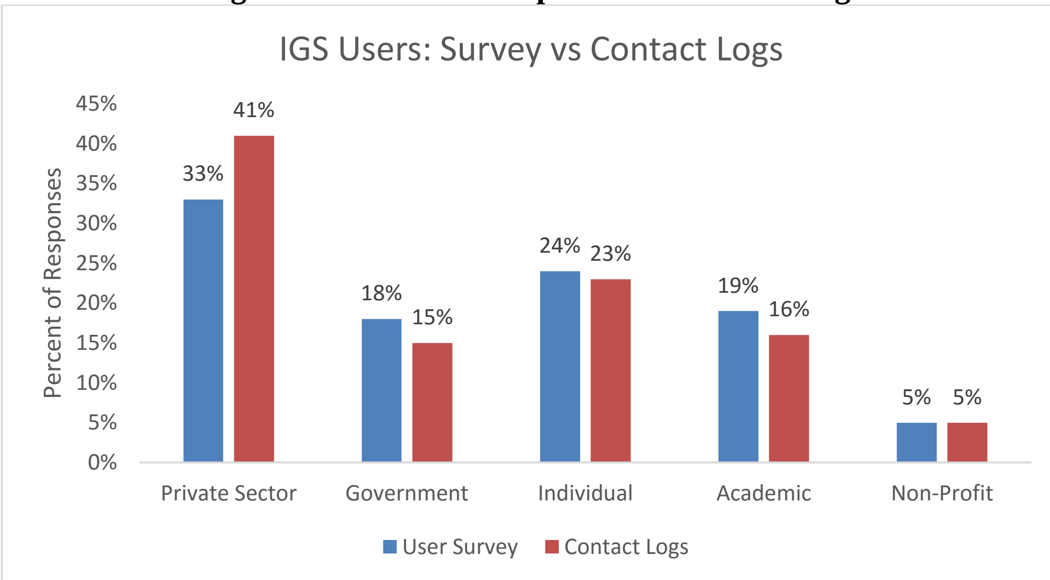
The survey collected information on the client's last use of IGS services. Specifically, it asked users to identify the purpose of the information request as well as alternatives available if IGS were to be unable to satisfy the request. These questions were then used to analyze the replacement cost of IGS information and the value of foregone information through abandoned projects. This methodology will cover the calculations for the replacement cost of IGS information.

The survey was release on February 23, 2017 and remained open for approximately three weeks. It targeted a total population of 769 IGS service users and received 213 usable responses for a total response rate of nearly 28 percent. The full questionnaire that was distributed to IGS users is included at the end of this appendix section

Distribution and Representativeness

The survey was initially distributed directly to the emails of the 769 recorded users of IGS services. Anonymous survey links were also distributed via Facebook, Twitter, and the quarterly IGS newsletter which have an estimated following of 229, 393, and 1500 individuals, respectively. While the targeted population does not represent a random sample of IGS Users, the breakdown of responses from government agencies, academic institutions, private industries, non-profit organizations, and individuals can be compared to information we were provided by the IGS; namely, its information request logs. From these logs, we were able to get an initial view of the companies and organizations that use IGS products and services. Private industries, notably engineering and environmental consulting firms, make up the largest portion of users who request information from the IGS, representing just over 40% of information requests. Figure T compares sector representation from the IGS User Survey to sector representation from the IGS information request logs.

Figure T: IGS User Sample versus Contact Logs



This proportion of uses by sector from the logs closely matches that in our survey responses. Some differences exist; the IGS User Survey appears to have under-sampled private sector actors. While this is expected due to the targeted, as opposed to randomized, distribution of our survey, the degree to which the survey respondents match what we learned from the information requests logs serves to validate the results of our analysis.

Replacement Cost of IGS Information

Identifying Market Value of Requested Services

Many of the goods and services provided by IGS are provided at a steep discount or for free. Therefore, in order to identify the market value on IGS services, IGS users were asked to identify and categorize the last piece of information they requested from the IGS. Users recalled the most recent service request in order to better represent a typical service request and avoid bias from encouraging respondents to think about the most expensive or demanding service requested.

Users were then asked what they would do if the IGS was unable to provide the most recent piece of requested information. The open-ended responses generated a wide-variety of alternatives from google earth and individual field work to competitive public entities and private sector consulting firms. Figure 2 shows the count of users from each sector that would have (1) obtained the information from another freely available source, (2) obtained the information directly, and (3) paid for the information from another source. Users were also given the option to say that they would not have obtained the information. These users were separated out and asked a different set of questions, as they could not be reliably asked to estimate a replacement cost for information that they would not replace.

Figure U: Count of Users by Sectors for Access to Alternatives

Obtained the information from another freely available source	
Sector	**Count**
Private Industry	17
Academic Institution	7
Government Agency	7
Individual	7
Non-Profit Organization	1
Total	39
Obtained the information directly, for example own fieldwork	
Private Industry	14
Academic Institution	7
Government Agency	5
Individual	4
Non-Profit Organization	2
Total	32
Paid for the information from another source	
Private Industry	13
Individual	6
Academic Institution	5
Government Agency	5
Non-Profit Organization	2
Total	13
Grand Total	102

After recalling the most recent project and identifying a potential alternative, respondents were then asked what they would have expected to pay from the alternative source as well as what they would have been willing to pay for that information. Questions were added for both what users would have expected to pay and what they would have been willing to identify any gaps in market price and user demand. Together, these responses were used to provide an estimate of the replacement cost of IGS services; the cost users would have been willing to pay if the IGS was unable to provide this information and instead an alternative service was required. In this case, the willingness to pay is used as a shadow price for the value that each piece of requested IGS information provides to its recipient.

As expected, in the majority of cases user expectations were identical to user willingness. For the few cases in which expectation was different than willingness to pay, we took the higher of the two values. This was done because, in many cases, the terminology may have confused respondents. For example, some respondents provided that they would expect to pay $200, while at the same time indicating that their willingness to pay was $10. In such a case, because the respondent already indicated that they would purchase the information, and that they expect that information would cost $200, we can safely assume that they would be willing to pay $200 for it. In some cases, respondents may have been confused about the wording of the questions and left it blank. Additionally, two outlier values were identified and removed or adjusted after comparing the value provided to respondents with similar demographics.

Furthermore, users were also asked to identify how crucial the last piece of IGS information was to their project. This question not only identified the importance of IGS information, but also allowed us to validate responses regarding expectation and willingness to pay. For example, some respondents listed an expectation to pay zero dollars as well as a willingness to pay zero dollars but then stated that the information was “legally required and crucial to project success.” In these cases, users should be willing to pay more than zero dollars for information that is legally required and crucial to project success; however, the question was assumed to be misunderstood. These responses were excluded from our average value.

The remaining responses represent IGS with an average per-use value of $3,066.14. While not every information request is valued at just over $3,000, we believe the average represents a lower bound estimate of all service requests from 2015 to 2016. When applied to the average number of IGS service requests from 2012 to 2016, this results in an annual valuation of $5,344,282.

Valuing Free Services and Web Information Access

Valuation of Online Services

Similar to the methodology listed above, the survey also included a set of questions that asked users to identify the most recent type of information access from IGS’s website. It then asked users to estimate what they would be willing to pay for this information. There were no outlier values identified in the results after comparing the value provided to respondents with similar demographics.

Of the 183 respondents that saw this question, 30 percent gave no response. The remaining 70 percent estimated the total value of information on IGS website at $745.79.

Identifying Online Users

While the IGS performs an average of 1,743 transactions a year, this number does not begin to account for the number of individuals that access their free services hosted by the IGS web servers. Free services range from geologic information on the website, geologic databases, photograph archives, and notably an interactive map with which users can compile their own information. The information viewed, collected, and compiled on the website by visitors is valuable, and in order to estimate the total value accessed we must estimate total use.

To do this, our team analyzed Google Analytics data provided to us by the IGS. In 2016, IndianaMap and PDMS, two of the largest tools housed on the IGS website, were accessed by 65,675 unique users (IP addresses). Because many users will have accessed the website on multiple devices (and thus multiple IP addresses), this figure was divided in half. Based on this, we estimate that 32,837 unique users access these major tools each year. Our decision not to include web users for other tools, such as IGS Map, was done in order to be as conservative as possible. Many users will have used a variety of tools on the website.

Admittedly, this method of estimating total users of the IGS web-based tools is imperfect. Many of the IP addresses may have navigated to the page unintentionally, or did so without have obtained any useful information. Due to these concerns, our approach factored in a final measure to ensure that our end result was as conservative as possible. Rather than trying to estimate how many times each of the 32,837 users utilized the website and then multiplying it by the $745 valuation derived from the survey, we chose to assume that each unique user made use of the website tools only one time per year. In this sense, we equated the $745 valuation with a hypothetical subscription fee, rather than a per-use value. By taking this valuation and multiplying it by the estimated web-users, we arrived at our valuation for web-based services of $24,489,848.

The IGS User Survey

DEMOGRAPHICS

1. What type of organization do you represent?
   A. Government Agency
   B. Academic Institution
   C. Private Industry
   D. Non-profit organization
   E. Individual

USE OF IGS INFORMATION

2. Which of the following activities does your organization engage in that requires the use of IGS information? **Check all that apply:**

Exploration and development

☐ Coal	☐ Groundwater and surface water
☐ Oil & Gas	☐ Other ______________________
☐ Industrial minerals (limestone, sand/gravel, clay)	

Environmental consulting

☐ NEPA process	☐ Clean air act
☐ Clean Water Act	☐ Safe Drinking Water Act
☐ RCRA	☐ SMCRA
☐ Other_______	

Natural Hazards

☐ Land slides	☐ Karst (sinkholes, drainages)
☐ Earthquakes	☐ Subsidence
	☐ Other_______

Engineering applications

☐ Buildings and foundation	☐ Karst (sinkholes, drainages)
☐ Roads/Highways	☐ Subsidence
☐ Railroads	☐ Other_______

Planning and zoning

☐ Zone decisions	☐ Building codes
☐ Landscape design and planning	☐ Waste disposal facilities

☐ Permitting industrial facilities	☐ Transportation ☐ Other_______

Property valuation

☐ For tax purposes	☐ Land acquisitions ☐ Other_______

3. How often do you make use of IGS information?
   A. 10 or more times per year
   B. 3-10 times per year
   C. 1-2 times per year
   D. Less than once per year

4. Describe how you typically use information provided by IGS:

VALUING REPLACEMENT COSTS

Information obtained by request

5. When was the last occasion that you received IGS information, products, or services **by contacting IGS** (e.g. by email, phone call, letter, or request form)?
   A. In the past month
   B. In the past 6 months
   C. In the past year
   D. More than a year ago

6. What did this information relate to? Please select the description that fits the best.
   - Natural resource extraction and use (energy, mineral, and water)
   - Geotechnical information (environmental, hazard, reclamation, sequestration, etc.)
   - Geologic materials (access, identify, analyze)
   - Archival information (images, pictures, data sets etc.)
   - Research methodologies and strategies
   - Educational information and materials
   - Other geological information (please explain): _____________

7. If IGS had not been able to provide you with this information, what would you or your organization have done?
   A. Paid for the information from another source
   B. Obtained the information directly, for example through doing your own field work.
   C. Obtained the information by a freely available source. If so, what source: ___________
   D. Not obtained the information **[SKIP TO QUESTION 11*]**

8. What would you have *expected* to pay for this information if IGS could not provide it (either

by paying a consulting firm or by obtaining it yourself)?

$______________

9. What would you have been *willing* to pay for this information if IGS could not provide it?

$______________

10. How important was obtaining this information to your project?

A. Legally required and also crucial to project success
B. Legally required but not crucial to project success
C. Crucial to project success, but not legally required
D. Useful but not crucial to project success
E. Not useful

An individual will only see question 11, 12, and 13 if they answered D to question 7. Otherwise, they will see questions 8, 9, and 10 then skip directly to question 14.

11*(SL). If you would not have obtained the information, which outcome is most likely?

A. We would **not** have proceeded with the project
B. We would have continued without the information.

12*(SL). If you would have proceeded with the project despite not receiving this piece of geological information, what impact would this lack of information have had on your project? **Check all that apply.**

A. Lack of information would not have had an impact
B. Increased uncertainty regarding project success

C. Increased the risk of environmental damage
D. Increased risk of safety concerns
E. Increased cost in other areas

13*(SL). If you had to forgo a project due to lack of geological information, what did you anticipate the total cost of that project to be?

$_________________

Info about freely available information

14. When was the last occasion you obtained information from IGS that is freely available through the IGS's website (**without having to contact them and request it**)?

A. In the past month
B. In the past 6 months

C. In the past year
D. More than a year ago

15. What did this information relate to? Please select the description that fits the best.
- o Natural resource extraction and use (energy, mineral, and water)
- o Geotechnical information (environmental, hazard, reclamation, sequestration, etc.)
- o Geologic materials (access, identify, analyze)
- o Archival information (images, pictures, data sets etc.)
- o Research methodologies and strategies
- o Educational information and materials
- o Other geological information: _______

16. If this information was not provided by IGS, what would you have been willing to pay to get it?

$_____________

17. What was the importance of this information to your work?
A. Legally required and also crucial to project success
B. Legally required but not crucial to project success
C. Crucial to project success, but not legally required
D. Useful but not crucial to project success
E. Not useful

BENEFITS AS A % OF PROJECT COSTS

18. What was the total cost of your last project that required geological information?

$_____________

19. What percentage of that project's costs could be associated with acquiring geological information?

%_____________

OTHER COMMENTS:

20. Is there anything else you would like to share relating to how IGS contributes to your work?

21. Would you be willing to participate in a roundtable discussion or be interviewed to further discuss your experiences using IGS information?

A. Yes
B. No

22. Email address (optional): ____________________________

APPENDIX C: INTERVIEWS

The interviews and roundtables serve to deepen and clarify our survey research results. These methods gathered information through open-ended questions. The roundtable discussion facilitated a conversation that provided each participant an opportunity to contribute by responding to and building off of each other. The interviews were individual discussions with targeted participants in the key industries IGS serves and works with. We selected participants for both the roundtables and interviews based on industry representativeness and interaction frequency with IGS. We minimized bias by integrating diverse perspectives of participants, and categorizing the information into parts of the report based on similarities, differences, importance, and relevance.

Interviews

We created an IGS frequent client list for potential interviewees, defining frequent clients as a client that used IGS services five or more times in a year. Some of these frequent clients served on IGS's advisory council. The interviewees were categorized into 6 industries: academia, engineering, consulting, energy/extraction, government agency, and insurance, totaling 54 candidates in total. Once a list of frequent clients was established, we contacted 15 private and public clients, including 6 members of IGS's advisory council. We also reached out to an additional four IGS contacts that were selected because of significant interactions with IGS. Two of these contacts were clients, one was a staff member, and the other was an Indiana University official.

Figure V: Interview Participants

Industry	Contacted	Interviewed
IGS staff	1	1
Academia	2	1
Engineering	2	1
Consulting	3	1
Energy/Extraction	6	3
Government	4	4
Insurance	1	1
Total	19	12

Roundtable discussions

IGS participated in a roundtable to clarify and expand our knowledge of IGS's products and services. Representatives from the research, coal, hydrogeology, geomapping, information technology, and oil and gas departments at the IGS were in attendance.

General Interview Questions:

1. How familiar are you with the IGS?
2. What specific IGS products and services do you use?

3. Which service or services do you see as the most valuable?
4. How often do you require the services of IGS in a year?
5. How would the absence of the services affect your work?
6. Are there any organizations that you would use as a substitute for geological information if IGS didn't exist?
7. In what ways do you think IGS is valuable to the state of Indiana?
8. What suggestions do you have in the event that the IGS had its funding expanded?
9. Do you have any further comments you would like to make at this time?

Roundtable Topics

1. Common organizations worked with in specific areas
2. Most valued services or products of IGS
3. If IGS did not exist, what would be the most immediate impact on Indiana?
4. What could IGS do with expanded funding and services?

APPENDIX D: IMPLAN

Table 11: IMPLAN Expenditure Inputs and Economic Multipliers*.

Industry	Economic Contribution Model w/Shadow Pricing	Economic Contribution Model	Economic Impact Model	Multiplier: Indirect Effect	Multiplier: Induced Effect
Labor & Compensation	$ 3,154,435.73	$ 3,154,435.73	$ 289,987.07	0	0.77536
111 Crop Farming	$ 45,437.30		$ -	0.446509	0.282169
115 Ag & Forestry Svcs	$ 45,437.30		$ -	0.125339	0.768465
211 Oil & gas extraction	$ 572,509.96		$ -	0.505267	0.217839
212 Mining	$ 354,410.93		$ -	0.314715	0.303995
213 Mining services	$ 363,498.39		$ -	0.524745	0.218093
221 Utilities	$ 617,947.26		$ -	0.146213	0.159799
311 Food products	$ 54,524.76		$ -	0.492799	0.158633
312 Beverage & Tobacco	$ 18,174.92		$ -	0.439776	0.148389
323 Printing & Related	$ 9,313.19	$ 9,313.19	$ -	0.30078	0.318192
324 Petroleum & coal prod	$ 663,384.55		$ -	0.14425	0.054777
327 Nonmetal mineral prod	$ 9,087.46		$ -	0.370643	0.261458
333 Machinery Mfg	$ 155,552.26	$ 1,065.45	$ -	0.323311	0.198451
334 Computer & oth electron	$ 192,697.06	$ 56,385.17	$ 1,388.06	0.327673	0.235031
335 Electircal eqpt & appliances	$ 9,087.46		$ -	0.306809	0.211394
337 Furniture & related prod	$ 5,612.50	$ 5,612.50	$ -	0.361249	0.291079
339 Miscellaneous mfg	$ 11,952.55	$ 2,865.09		0.254874	0.291535
443 Electronics & appliances stores	$ 45,437.30		$ -	0.196665	0.427855
447 Gasoline stations	$ 5,042.34	$ 5,042.34	$ -	0.291341	0.395967
448 Clothing & accessories stores	$ 73,070.00	$ 370.32	$ -	0.357857	0.352225
453 Misc retailers	$ 61,409.84	$ 25,060.00	$ 920.06	0.22403	0.411341
481 Air transportation	$ 3,831.80	$ 3,831.80	$ -	0.379958	0.265437
484 Truck transportation	$ 2,716.84	$ 2,716.84	$ 165.55	0.371818	0.387527
485 Transit & ground passengers	$ 39,981.24	$ 39,981.24	$ 3,802.12	0.277646	0.506594
492 Couriers & messengers	$ 2,175.99	$ 2,175.99	$ -	0.296405	0.365553
511 Publishing industries	$ 132,403.26	$ 5,178.82	$ 236.00	0.344173	0.291128
515 Broadcasting	$ 45,437.30		$ -	0.372803	0.351895
516 Internet publishing and broadcasting	$ 95.43	$ 95.43	$ -	0.329008	0.359715
517 Telecommunications	$ 63,646.92	$ 34.70	$ -	0.375159	0.194818
518 Internet & data process svcs	$ 154,486.81		$ -	0.299599	0.274772
519 Other information services	$ 227,186.49		$ -	0.374828	0.337101
521 Monetary authorities	$ 54,524.76		$ -	0.269493	0.196019
523 Securities & other financial	$ 27,262.38		$ -	0.457796	0.341935
524 Insurance carriers & related	$ 1,105,891.34	$ 6,308.72		0.309458	0.305779
525 Funds- trusts & other finan	$ 182,896.14	$ 37,496.78		0.585372	0.188516
531 Real estate	$ 45,437.30		$ -	0.221021	0.084138
532 Rental & leasing svcs	$ 13,981.90	$ 13,981.90	$ 3,627.05	0.354273	0.401393
541 Professional- scientific & tech svcs	$ 10,815,875.70	$ 65,410.95	$ 55,247.00	0.29548	0.502424
551 Management of companies	$ 209,011.57		$ -	0.32133	0.483132
561 Admin support svcs	$ 357,041.56	$ 20,805.55	$ 290.00	0.228141	0.512317
562 Waste mgmt & remediation svcs	$ 45,437.30		$ -	0.338729	0.317213
611 Educational svcs	$ 5,584,609.23	$ 68,521.23	$ 60,930.81	0.356144	0.49369
623 Nursing & residential care	$ 45,437.30		$ -	0.245689	0.513231
624 Social assistance	$ 109,049.52		$ -	0.31925	0.527674
712 Museums & similar	$ 136,311.89		$ -	0.33298	0.284442
713 Amusement- gambling & recreation	$ 127,224.43		$ -	0.21913	0.313032
721 Accomodations	$ 36,349.84		$ -	0.332141	0.312021
811 Repair & maintenance	$ 43,774.72	$ 34,687.26	$ -	0.230344	0.469016
813 Religious- grantmaking- & similar orgs	$ 272,623.79		$ -	0.454093	0.582337
814 Private households	$ 18,174.92		$ -	0	0.768277
92 Government & non NAICs	$ 7,024,606.30			0.036082	0.607542

Explanation: The first column in this model lists the three-digit North American Industry Classification System codes used to categorize IGS expenditures. Columns two through four represent the expenditures associated with each industry code that were used as inputs to the three input-output models described in this paper. The final two columns are the multipliers used by IMPLAN, which estimate the percentage of direct expenditures that ultimately become indirect and induced economic effects. These multipliers are based on a complex matrix series based on the supply chain and proportional expenditures of each industry, within the boundaries of the State of Indiana. Support for this model was provided by the Indiana Business Research Center.