Montana Tech: Annual Program Review

Department: Geological Engineering

Program: BS Geological Engineering

Department Head: Chris Gammons

Year Under Review: 2014-2015

Submitted: January 15th, 2016

Assessment Committee Review: Spring 2016

Department: Geological Engineering
Degree: Bachelors of Science

Program Educational Objectives:
Program educational objectives are broad statements that describe what graduates are expected to attain within a few years of graduation. Program educational objectives are based on the needs of the program's constituencies. The current educational objective of the Department of Geological Engineering, as of Fall 2015, is as follows:

> *"to enable graduates to embark upon and successfully pursue professional careers in the field of Geological Engineering."*

The faculty of the Department recently voted to add a second part to this objective statement, which reflects our increasing graduate student enrollment, and the fact that many of our undergrad students go on to pursue M.S. or Ph.D. degrees at Montana Tech or other institutions:

> *"to provide a firm foundation for graduate studies in geological engineering and related field"*

The Department is waiting for feedback from our Industry Advisory Board to formally adopt this second objective into our program. We anticipate it will be approved in 2016.

Student Outcomes:
Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program. The fifteen Geological Engineering program outcomes are as follows.

Students graduating from the Geological Engineering program at Montana Tech should attain:

a. an ability to apply knowledge of mathematics, science, and engineering
b. an ability to design and conduct experiments, as well as to analyze and interpret data
c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d. an ability to function on multi-disciplinary teams
e. an ability to identify, formulate, and solve engineering problems
f. an understanding of professional and ethical responsibility
g. an ability to communicate effectively
h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i. a recognition of the need for, and an ability to engage in life-long learning
j. a knowledge of contemporary issues
k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
l. demonstrated proficiency in the engineering sciences, including statics, properties/strengths of materials, and geomechanics

m. demonstrated proficiency in geological science topics that emphasize geological processes and identification of minerals and rocks
n. demonstrated ability to visualize and solve geological engineering problems in three and four-dimensions (space and time)
o. demonstrated ability to apply the principles of geology, elements of geophysics, geological and engineering field methods, and engineering knowledge to design solutions to geological engineering problems

Outcomes a through k come directly from ABET EAC and are common to all engineering programs. Outcomes l through o are derived from the ABET EAC program-specific criterion for Geological and Similarly Named Programs. When changes and modifications are made and adopted by ABET, they are presented to the faculty and to the Geological Engineering Industrial Advisory Board for adoption by our program.

Student Outcomes

Table 1 summarizes courses required for our B.S. degree that are taught by faculty in the Department of Geological Engineering. Each course is mapped to a specific student outcome (a through o above). So, for example, outcome "j ", "a knowledge of contemporary issues", is a major topic covered in Geo 101 (Physical Geology) and a minor topic covered in Geo 104 (Intro to Geological Engineering), Geo 420 (Hydrogeology) and Geo 440 (Engineering Geology). For ABET accreditation, our Department provides detailed assessment information for each of the outcomes a through o for courses in Table 1 that are listed with an asterisk (*). A detailed assessment of outcomes a through o is not available at this time, but is in the process of being completed for the GeoE department's ABET accreditation visit in 2016.

In addition to the courses listed in Table 1, each undergraduate student in Geological Engineering must pass a set of upper level Technical Electives. Most GeoE students select one of the following four options: Hydrogeology, Geotechnical Engineering, Mining Geology, or Petroleum Geology. Each of these options has a set of 12 to 15 credits of technical electives that are required. Table 2 is a summary of the technical electives for each option in our program. For example, if a student wants to graduate with a B.S. degree in Geological Engineering with the Hydrogeology Option, they would take GeoE 422 (Groundwater Flow Modeling), GeoE 429 (Field Hydrogeology… a 2-week summer course), ECIV 486 (Soil Mechanics and Foundation Design), and GeoE 528 (Contaminant Transport). It is also possible for a student, in consultation with his/her advisor, to design their own set of technical electives. Because none of these technical elective courses are taken by all students in our program, we do not provide detailed assessment for these courses in terms of student outcomes. However, many of the outcomes a through o are covered as minor or major topics in these technical elective courses.

Table 1. Relationship of Geological Engineering Courses to Program (Student) Outcomes. Level of emphasis is indicated as "MAJOR" or "some". A blank entry indicates little or no emphasis on that outcome. An asterisk (*) means that this course is used for assessment for this outcome.

	Outcome														
Course	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*	*o*
101	some	some						some *		MAJOR *			MAJOR	some	
104	some	some *	some	some		some	some	some	some	some	some			some	
204	some												MAJOR *		some
209		some									some		MAJOR *	MAJOR *	some
257	some										some		MAJOR *	Some	
259	some	some					some				some		MAJOR		some
403	some	some			some						some	MAJOR *	some	MAJOR *	MAJOR *
409	some	MAJOR *	some	MAJOR *	some		some	some			MAJOR *		MAJOR	MAJOR *	MAJOR *
410W	MAJOR *	MAJOR	some *		some		MAJOR *	MAJOR *						MAJOR *	
420	MAJOR *	MAJOR *	some	some	MAJOR	some *	Some	some		some	MAJOR *			MAJOR	MAJOR
440	MAJOR	some	some *	some	MAJOR *	some	Some *	some	MAJOR *	some	MAJOR	MAJOR *	some	some	MAJOR
499	some	some	MAJOR	MAJOR *	some	some	MAJOR	some	some		some				MAJOR

Courses: Geo 101, Physical Geology; Geo 104, Introduction to Geological Engineering; Geo 204, Mineralogy and Petrology; Geo 209, Introduction to Field Geology; Geo 257, Sedimentology and Petroleum Geology; Geo 259, Sedimentology Lab; GeoE 403, Structural Geology for Engineering; GeoE 409, Field Geology and Geophysics (6 week summer class); GeoE 410W, Mining Geology; GeoE 420 Hydrogeology for Engineers; GeoE 440, Engineering Geology; GeoE 499, Senior Design Project.

Table 2. Technical Electives required for different options in the Geological Engineering B.S. degree

Geotechnical Option		
GeoE 541	Advanced Engineering Geology	3 credits
GEoE 542	Slope Stability Analysis and Design	3 credits
ECIV 486	Soil Mechanics and Foundation Design	3 credits
MIN 520	Geomechanics	3 credits
GeoE 406	Geomorphology and Photogeology	3 credits
Hydrogeology Option		
GeoE 422	Groundwater Flow Modeling	3 credits
GeoE 429	Field Hydrogeology	2 credits
ECIV 486	Soil Mechanics and Foundation Design	3 credits
GeoE 528	Contaminant Transport	3 credits
Mining Option		
Min 215	Mining Methods	3 credits
EMET 232	Process of Particulate Systems	2 credits
EMET 234	Particulate Systems Lab	1 credits
MIN 310	Computer Aided Mine Design	1 credits
GeoE 411	Metallic Ore Deposits	3 credits
Min 418	Ore Reserve Estimation	3 credits
Petroleum Option		
PET 201	Elements of Petroleum Engineering	3 credits
PET 202	Petroleum Field Practices	1 credit
PET 205	Petroleum Engineering Lab	1 credit
PET 301	Drilling Engineering	3 credits
PET 304	Petrophysical Rock Properties	3 credits
PET 348	Petroleum Well Logging	3 credits
GeoE 457	Subsurface Methods in Petroleum Geology	3 credits

Core Theme 1: Education and Knowledge

As found under Objective 1, Indicator of Achievement E in YOR: Describe direct measures of student knowledge (e.g., Licensing Exams, Capstone Course, Senior Projects).

Montana Tech administers the Educational Testing Service (ETS) Proficiency Profile Exam to measure general education outcomes in critical thinking, reading, writing, and mathematics. Undergraduate students in our department scored very well on this test, both compared to Montana Tech as a whole, and compared to U.S. institutions as a whole. Pertinent data are summarized in Table 3 below.

Table 3: Results of 2014-2015 ETS Proficiency Profile Exam

		Reading Level 1	Reading Level 2	Critical Thinking Level 3	Writing Level 1	Writing Level 2	Writing Level 3	Math Level 1	Math Level 2	Math Level 3
GeoE Dept. n = 12	Proficient	100%	83%	0%	83%	50%	8%	100%	92%	50%
	Marginal	0%	17%	67%	17%	33%	50%	0%	8%	42%
	Not proficient	0%	0%	33%	0%	17%	42%	0%	0%	8%
Montana Tech n = 323	Proficient	90%	69%	11%	74%	33%	8%	88%	73%	35%
	Marginal	5%	18%	44%	20%	40%	42%	10%	15%	33%
	Not proficient	5%	13%	45%	6%	27%	50%	2%	12%	32%
All U.S. schools n = 124588	Proficient	66%	39%	8%	65%	23%	9%	59%	36%	13%
	Marginal	19%	18%	19%	25%	35%	27%	21%	23%	18%
	Not proficient	15%	43%	73%	10%	42%	63%	20%	42%	69%

The following table shows the percentage of students from other U.S. institutions that performed lower than our Department, and lower than Montana Tech as a whole, for individual test disciplines. In other words, undergraduate students in GeoE at Montana Tech performed 96% to 100% better than students at comparable academic standing at other U.S. institutions, across the board.

Table 4. Percentage of students in U.S. who scored below our students on the ETS exam, by category

	Total Score	Critical Thinking	Reading	Writing	Math	Humanities	Social Sciences	Natural Sciences
GeoE Dept. n = 12	98%	97%	100%	96%	100%	99%	98%	100%
Montana Tech n = 323	94%	97%	96%	77%	100%	94%	92%	98%

All undergraduate students in the Geological Engineering program are required to take the Fundamentals of Engineering (FE) exam before earning their diploma. They are not required to pass the exam, but they are required to take the exam. As proof that they have taken the FE exam, each student must submit a copy of their receipt and photo ID to the instructor for GeoE 499 (Senior Design). If the student fails to do this, they receive an incomplete in this course and cannot graduate. When they take the exam and submit the required receipt, the incomplete is lifted. The student must also submit a copy of their receipt to the Head of the Department, who ensures that the student has taken the FE exam before signing off on their diploma. **During the 2014-2015 academic year, 9 of our undergraduate students took the exam, and 6 passed, for a pass rate of 67%.** This is somewhat below the total pass rate for all Montana Tech students of 81%. Given the small number of students in our Department who took the test (n = 9), it is hard to make a statistical comparison. Also, it is not uncommon for students who fail the test once to retake and pass the exam on their 2nd try.

As found under Objective 2, Indicator of Achievement A in YOR: What extracurricular educational opportunities (and participation rate) are available to students in your program? (e.g., Undergraduate Research Program (URP), Seminar Activities, Conference Attendance, Guest Lectures, and Field Trips)

Montana Tech and the Department of Geological Engineering strongly encourage our students to undertake at least one Undergraduate Research Program (URP). A URP is an independent research project that has a duration of 1 semester, 2 semesters, or one summer. Approximately a third of our students do this, especially students in the Geotechnical Engineering and Hydrogeology Options. The reason that these options are more active with URP projects is that the faculty in these areas have more research grant money and active projects. Students who undertake a URP project must give an oral or poster presentation at one of the semi-annual Undergraduate Research Symposia, and are strongly encouraged to present a poster at Montana Tech's annual "Techxpo" (Tech Expo), which is a one-day event held near the end of the Spring Semester. They are also encouraged to present their research at a professional conference. Examples of conferences that have been attended by undergraduate students in Geological Engineering in the past 5 years include (but are not limited to): SME (Society of Mining, Metallurgical Engineers); GSA (Geological Society of America, both regional and national meetings); Montana AWRA (American Water Resources Association); MDOC (Mine Design Operations and Closure Conference); and the U.S. Rock Mechanics Symposium. Students who wish to attend a professional meeting are typically given Department support by picking up registration and partial travel costs.

The Research Office of Montana Tech sponsors an active seminar program, as does the Montana Bureau of Mines and Geology. The latter is especially active in Spring semester, with invited talks almost every week. Many GeoE undergrads regularly attend these seminars. At the present time, our Department does not have a formal Geology or Geological Engineering seminar class, partly because many potential speakers are already booked for talks through the MBMG Seminar Series. Guest lectures are frequently arranged for recent alumni from our Department who have gone on to successful careers. These lectures are sometimes scheduled outside of the classroom, and sometimes within courses such as Introduction to Geological Engineering, Hydrogeology, and Engineering Geology. Many of our alumni live in the greater Butte area, so it is relatively simple to arrange a visit during or after school hours. In the past, the Geology Club has arranged guest speakers on various career-oriented topics, although not so much in recent years.

The GeoE curriculum places a heavy emphasis on field trips. For extra-curricular field trips, the Geology Club typically organizes one or two trips each semester, often to local mineral-collecting sites. Students are also often invited to participate in field trips to sites where on-going research projects by grad students and faculty are being conducted.

As found under Objective 3, Indicator of Achievement A in YOR: In what ways does your program prepare graduates for a successful career in addition to curricular preparation? (e.g., Internships, professional exam preparation, specialized training in software, and IAB feedback)

Most of the undergraduate students in GeoE have at least one (sometimes multiple) summer internships during their time at Montana Tech. Montana Tech has campus-wide Career Fairs in both the Fall and Spring semesters. In addition, the Montana Bureau of Mines and Geology regularly hires undergraduate and graduate students for summer (full-time) or in-semester (part-time) internships, especially students with an interest in hydrogeology. Our recently re-organized Industry Advisory Board has formed a committee dedicated to "Placement" for our undergraduate students in both summer jobs

and permanent jobs. One area where our students have recently had difficulty finding internships and jobs is in petroleum geology. This is partly due to a dramatic downturn in the oil and gas exploration industry, and partly to a perception on the part of the oil and gas industry that "geological engineers with a specialty in petroleum geology" are not as valuable to their company as "petroleum engineers". This second observation is anecdotal. The department faculty have discussed this issue with our IAB, and we will be thinking of ways to improve the marketability of our petroleum geology students. Our students get plenty of training in specialized software programs that have become industry standards: we are always looking for new ways to bring software into our upper-level classes, and periodically add new PC's to our teaching labs.

CORE THEME 2: Student Achievement

As found under Objective 3, Indicator of Achievement A in YOR: What academic distinction opportunities are available to your students and what distinctions have been achieved over the last year? (e.g., Merit Scholarships, distinction based on GPA (e.g., Deans List), and team competitions.)

The GeoE Department had 11 graduating seniors in the Spring 2015 commencement. Of these, 6 graduated with Honor, and one with highest Honor. The winner of the Outstanding Achievement Award in Geological Engineering was Mandy Brewer (now an M.S. student at Montana Tech), and the winner of the Chester Steele award for outstanding graduating senior in mining geology was Haylee Patterson.

In 2015, there were 34 undergraduate students enrolled in Geological Engineering (this does not include students in the common Freshman class). 18 of these students received merit-based institutional scholarships totaling $106,456; 8 received external scholarships totaling $21,500; 3 received tuition-fee waivers, totaling $17,869. In addition, 8 of our undergraduate students received WUE or Advantage status (which allows out-of-state students to pay 1.5 x resident tuition). Each year, we offer an annual "Ralph Mitchell scholarship" to a new incoming student from the state of California. The process is highly selective and includes written essays and phone interviews. The endowed Mitchell scholarships carry 4 years of complete support, including tuition waivers and a living stipend.

The Department of Geological Engineering had 25 M.S. graduate students in 2015. 6 of these students received partial or full graduate teaching assistantships ($30,000 in support), and about 2/3rds of the students received partial or full in-state tuition waivers (another $30,000 in support). Approximately 1/3 were eligible for WICHE status, which allows students from any Western state to qualify for in-state tuition in the Geosciences M.S. program at Montana Tech. In addition, the Department of Geological Engineering distributed $24,000 in institutional scholarship money to graduate students, on both a competitive and need basis.

CORE THEME 3: Engaged Faculty

Department Faculty:

	Full time tenure track	Full time non-tenure track	Part time faculty
Number of department faculty	5	0	0
Number of department faculty reviewed this year	5	0	0
Objective 1, Indicator of Achievement A: Number of department faculty reviewed this year who met departmental standards in teaching	4	0	0
Objective 2, Indicator of Achievement A: Number of department faculty reviewed this year who met departmental standards in research, scholarly activity, and/or professional development	5	5	5
Objective 3, Indicator of Achievement A: Number of department faculty reviewed this year who met departmental standards in service to their profession, the campus, and/or the community	5	5	5

The Department of Geological Engineering has excellent teachers. Four out of five of our faculty have received the Rose and Anna Busch award for excellence in teaching (one individual has won the award 3 times). Nonetheless, one of our tenured faculty had student evaluation scores in 2015 that were below our Departmental Standards. The Department Head met with the faculty member in question and discussed possible ways that the courses in question could be improved. The GeoE department is also one of the most active departments at Montana Tech in terms of research and supervision of graduate studies. Three of our faculty have won the Montana Tech Distinguished Researcher Award (one individual has won the award twice). One of our faculty (Dr. MacLaughlin) received national recognition from the Geosciences Division of the U.S. Council on Undergraduate Research by receiving their annual Undergrad Research Mentor Award (Fall, 2014). We currently have the most M.S. grad students (21) of any program in the School of Mines and Engineering. In 2015, GeoE faculty brought in over $1,000,000 in external funding, including an NSF Major Research Infrastructure (MRI) grant to purchase a sophisticated earthquake shake table for geotechnical experiments. As indicated by the CVs at the end of this report, our faculty and students regularly publish their research in scholarly journals and conference proceedings. Each member of the department is required to sit on at least one major campus committee, and to be involved with professional societies.

CORE THEME 1: Education and Knowledge
Program Evaluation

Objective 1, Indicator of Achievement C: Strengths:

a. The curriculum in the GeoE department provides students with a strong background in geosciences, as well as applied topics in each of our four areas of emphasis: hydrogeology, mining geology, petroleum geology, and geotechnical engineering.
b. Undergraduate students in GeoE take the requisite courses in mathematics and engineering needed to pass the Fundamentals of Engineering exam, the first step in obtaining a Professional Engineering License.

c. Undergraduate students in GeoE get extensive hands-on field experience through summer field camps and in-semester field trips in their required courses.
d. Graduates of the GeoE department continue to have a near 100% placement rate with nationally competitive starting salaries. Many undergraduate students continue for an M.S. degree before leaving Montana Tech. Our M.S. program is flexible, and includes both engineering and non-engineering options, thesis and non-thesis options.
e. Most faculty members in the department are actively engaged in research, including procurement of external grants and publication of scholarly work in refereed journals. We have been consistently successful in obtaining state-of-the-art equipment in geotechnical engineering and, more recently, mineralogy lab equipment (e.g., portable XRF, portable short-wave infra-red analyzer (SWIR))m, two new petrographic microscopes.

Objective 1, Indicator of Achievement D: How will the program maintain the strengths?

a. The GeoE department continually revises all courses in our curriculum in response to student evaluations, review of new textbooks and online course material, faculty attendance at engineering and geological conferences, and input from our Industry Advisory Board (IAB).
b. Unlike many universities which see funds for field trips and summer field schools being slashed, Montana Tech and the GeoE Department have always stressed the importance of field trips and field camps. These courses are imbedded in our curriculum, and we have no plans to take them out.
c. While inactive for a 3-year period, the GeoE IAB has recently undergone a major overhaul. The IAB has two new co-chairs and a roster of over 25 professionals. The IAB has formed 5 sub-committees which cover the following core areas: 1) Funding; 2) Curriculum; 3) Strategic Planning; 4) Job Placement; and 5) Enrollment. The new IAB met twice in 2015 and are planning at least 2 meetings for 2016. Each subcommittee is in the process of drafting up action items for approval and implementation. For example, the "funding" committee has a plan to institute two new summer "Field Geology" scholarships in time for the 2016 Field Geology and Geophysics course.
d. The department recently developed its own Guidelines for Promotion and Tenure. This document explicitly states the program's standards for achieving "satisfactory" and/or "excellent" performance in the areas of teaching, research, and service. A copy of our current "Guidelines" document is included as an Appendix at the end of this report.
e. In the past 4 years, Montana Tech has instituted a "Merit Pay" system in which faculty who are showing high achievement in Teaching, Research, and/or Service can receive a raise of $2000 to their base salary. Four out of five faculty in the Geological Engineering department have received Merit Pay awards. The Merit Pay system provides motivation for faculty to continue to excel, which is especially important for full professors who are already at the highest possible pay scale at Montana Tech.

Objective 1, Indicator of Achievement C: Weaknesses:

a. Total undergraduate student enrollment in GeoE, although steady for over 15 years, is nonetheless lower than desirable. Enrollment could increase by roughly a third (from 40 to 60) without requiring additional space or faculty.

b. The high teaching load for faculty in GeoE is detrimental to supervision of graduate students and undergraduate research projects, as well as performance of cutting-edge research.
c. The department has not undertaken any formal exit surveys or recent alumni polls in several years. This needs to be done, especially with an ABET accreditation year coming up in 2016.
d. The current department chair has found it very difficult to carry out administrative duties while still carrying a full teaching load and higher-than average research load.

Objective 1, Indicator of Achievement D: How will the program address the weaknesses?

a. The new "Enrollment Committee" of the IAB may come up with some fresh ideas on how the department can grow our undergraduate enrollment. One action that needs to take place is an overhaul of our department website. This is a work in progress, as Montana Tech has recently hired a new webmaster. The new Freshman Engineering common-course scheduling for first year students may have had a slight positive impact on our GeoE enrollment. We presently have 15 students in Geological Engineering enrolled in our 2nd-year classes, which is more than the long-term average. One reason that we may be seeing an uptick in GeoE sophomores is that all students in the School of Mines and Engineering now take Physical Geology (Geo 101) in their first year. As well, the new freshmen program includes a set of Open Houses for first-year students who have not made up their mind yet about which programs they want to major in. Students visit the Geological Engineering program and learn what our field of study is all about. They visit the labs and meet several of the professors and students. It is an opportunity to ask questions. These Open Houses may have had a positive effect on enrollment, although more years of data are needed to be sure of this.
b. The department has begun the process of decreasing teaching loads for research-active faculty and increasing loads for non-active faculty. Some graduate-level courses will be taught on alternate years instead of every year, so that the faculty will have fewer classes to teach each semester, while still offering all classes to students on a 2-year rolling average.
c. The department plans to institute an exit-survey for our Spring 2016 graduating students (n = 7) as well as an on-line questionnaire for recent alums as another way to assess our outcomes.
d. We have instituted a "rotating department chair" format whereby each new department head serves in this capacity for a minimum of 3 years and maximum of 5 years. This means that faculty who are most active in research or grad student advising will not be strapped with the added responsibility of heading the department for more than a 3 year period.

Other actions leading to program improvement (e.g., develop a new course):

a. In the fall of 2015, visiting instructor Lori Babcock developed a new course entitled "Carbonate Petrology". This 3 credit course (with lab) focused on the identification and occurrence of carbonate rocks in sedimentary environments, with special emphasis on applications to oil and gas exploration. The course was well-received by both undergrad and grad students, including students from the Petroleum Engineering department. We hope to offer this new course as an elective for students in the Petroleum Geology option on an every-other-year basis.

Glossary of Terms:

Student Outcome: Program outcomes describe what students are expected to know and able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program.

Performance criteria: Performance criteria are measurable statements and indicate the specific characteristics students should exhibit in order to demonstrate desired attainment of the learning outcomes.

Strategies: The courses or activities that are designed to provide opportunities for students to learn, practice, demonstrate and/or get feedback on their performance on the performance criteria. This identifies how the curriculum is aligned with the projected outcome.

Assessment Method: The assessment instrument(s) that are used to assess student learning. (examples: Student Evaluation of Courses, Capstone Course/Project, SSI Survey, Graduate Survey, Alumni Survey, Employer Survey, Exit or Licensing Exam, Advisory Board, Specialized Accreditation, Internship, Curriculum review, Evaluation of Faculty, pre-post exams, seminar, and URP projects

Source of assessment:: The course or other setting in which the assessment data will be collected. For program assessment it is not necessary—or even desirable—to collect data from every course or setting in which the performance criteria are addressed, nor are data needed from every student. Sampling strategies can be used where appropriate.

Time of data collection: Identifies when the assessment data will be collected.

Assessment Coordinator: The person responsible for being sure that the assessment data are collected.

Evaluation of Results: The person/group responsible for determining the meaning of the assessment results and making recommendations for action.

Results: Report of the data collection and analysis process.

Actions: Based on the findings, the actions taken which have been recommended to improve student performance.

Second- Cycle Results: The results based on assessment after taking action on earlier recommendations.

Core Theme 1, Objective 1, Indicator of Achievement B: **Core Theme 4, Objective 1, Indicator of Achievement A:**

Assessment Year - 2015 **Student Diversity**

MAJOR: GL Geological Engineering

	Full Time (F) and Part Time (P)	Freshman	Sophomore	Junior	Senior	Post Bacc	Total Graduate	Total Undergrad	%Female Gender	%Underrepresented Ethnicity	%Montana Students	%Out-of-State Students	%International	%PELL
Fall 2014	F		9	9	14	2								
	P							34	41%	3%	29%	50%	21%	16%
Fall 2013	F	6	13	10	10	4								
	P							43	42%		42%	44%	14%	21%
Fall 2012	F	9	9	8	19	2								
	P		1		2			50	42%	4%	54%	34%	12%	40%
Fall 2011	F	7	9	9	18	3								
	P							46	41%	2%	52%	30%	17%	21%
Fall 2010	F	6	9	14	8	2								
	P							39	31%	8%	46%	33%	21%	35%

Core Theme 1, Objective 1, Indicator of Achievement B:

Degrees Awarded - Assessment 2015

Major	Minor	Certificate	Associate	Bachelor	Master
Geological Engineering					
2013-2014				8	
2012-2013				13	
2011-2012				3	
2010-2011				5	
2009-2010				0	

Graduate Survey

BS Geological Engineering

Year	# of Graduates	# of Graduates Reporting	Core Theme 2, Objective 2 Indicator of Achievement A: Degree Related Employment	Professional Employment	Outside Degree Area	Core Theme 2, Objective 2 Indicator of Achievement B: Continuing Education	Military	Not Currently Seeking	Seeking Employment	Core Theme 2, Objective 2 Indicator of Achievement A: Placement
2012	3	3	3	0	0	0	0	0	0	100%
2011	5	5	3	0	0	2	0	0	0	100%
2009	11	11	7	0	1	3	0	0	0	100%

Core Theme 1, Objective 4, Indicator of Achievement B

Geological Engineering

College Name	Number of First Time Freshman Transferring (2007-2013 Cohort)	Average Number of Credits Earned at Tech Prior to Transfer
CENTRALIA COLLEGE	1	30
EVERETT COMMUNITY COLLEGE	1	49
GREAT FALLS COLLEGE - MONTANA STATE UNIVERSITY	1	0
MONTANA STATE UNIVERSITY - BOZEMAN	3	22
SOUTHERN NEW HAMPSHIRE- 09WEEK	1	46
UNIVERSITY OF ALASKA ANCHORAGE	1	30
UNIVERSITY OF MONTANA	3	12

Full Time Faculty Assessment 2015
Core Theme 4, Objective 1 Indicator of Achievement A: Faculty Diversity (Fall 2014)

Department	Type	# of Faculty	% Female	% Non-Resident Alien	% Under Represented
Geological Engineering					
	F(a) - Full Time Tenure Track Faculty	5	40%	0%	0%
		5	40%	0%	0%

Faculty Analysis Courses Data - Assessment 2015

Core Theme 3, Objective 1 Indicator of Achievement A:

Instructor	Course	Credits	Enrolled	Core Theme 1, Objective 2, Indicator of Achievement B: Distance Delivery
Department	**Geological Eng**			
Fall 2014				
	GEO 101 11 Intro to Physical Geology	0	30	
	GEO 101 12 Intro to Physical Geology	0	18	
	GEO 101 14 Intro to Physical Geology	0	10	
Christopher Hall Gammons				
	GEO 101 01 Intro to Physical Geology	3	59	
	GEOE 501 01 Montana Geology	2	11	
	GEOE 531 01 Acid Rock Drainage	3	18	
	GEOE 590W 01 Graduate Research	variable	2	
	GEOE 599W 01 Thesis Research	variable	4	
Diane Wolfgram				
	GEOE 410 01 Mining Geology	3	12	
	GEOE 410 11 Mining Geology	0	12	
Glenn Shaw				
	GEOE 420 01 Hydrogeology For Engineers	3	36	
	GEOE 420 11 Hydrogeology For Engineers	0	36	
	GEOE 498 03 Internship	1	1	
	GEOE 528 01 Contaminant Transport	3	14	
	GEOE 528 11 Contaminant Transport	0	14	
	GEOE 599W 03 Thesis Research	6	1	
Larry N. Smith				
	GEO 209 01 Intro To Field Geology	1	15	
	GEO 257 01 Sedimentology and Pet Geology	3	121	
	GEO 259 01 Sedimentology Stratigraphy Lab	1	18	
	GEOE 591 03 Special Topics	3	8	
	GEOE 591 11 Special Topics	0	8	
	GEOE 599W 04 Thesis Research	8	1	
Mary M MacLaughlin				
	GEOE 440 01 Engineering Geology	3	19	
	GEOE 440 11 Engineering Geology	0	19	

Faculty Analysis Courses Data - Assessment 2015

Core Theme 3, Objective 1 Indicator of Achievement A:

Instructor	Course	Credits	Enrolled	Core Theme 1, Objective 2, Indicator of Achievement B: Distance Delivery
	GEOE 490 02 Undergraduate Research	1	2	
	GEOE 542 01 Slope Stability Analy & Design	3	6	
	GEOE 542 11 Slope Stability Analy & Design	0	6	
	GEOE 599W 02 Thesis Research	variable	2	
Paul Conrad				
	GEOE 499W 01 Geological Eng. Design Project	3	2	
Spring 2015				
Christopher Hall Gammons				
	GEO 204 01 Intro Mineralogy-Petrol w/ lab	3	33	
	GEO 204 11 Intro Mineralogy-Petrol w/ lab	0	10	
	GEO 204 12 Intro Mineralogy-Petrol w/ lab	0	23	
	GEOE 411 01 Metallic Ore Deposits	3	14	
	GEOE 411 11 Metallic Ore Deposits	0	14	
	GEOE 590W 01 Graduate Research	variable	3	
	GEOE 599W 01 Thesis Research	variable	6	
Diane Wolfgram				
	GEOE 403 01 Structural Geol for Engineers	3	15	
	GEOE 403 11 Structural Geol for Engineers	0	15	
	GEOE 457 01 Subsurface Meth In Pet Geol	3	102	
	GEOE 457 11 Subsurface Meth In Pet Geol	0	42	
	GEOE 457 12 Subsurface Meth In Pet Geol	0	60	
Glenn Shaw				
	GEO 101 02 Intro to Physical Geology	3	83	
	GEOE 422 01 Groundwater Flow Modeling	3	8	
	GEOE 422 11 Groundwater Flow Modeling	0	8	
	GEOE 599W 03 Thesis Research	variable	3	
Larry N. Smith				
	GEO 101 01 Intro to Physical Geology	3	138	
	GEO 101 11 Intro to Physical Geology	0	34	
	GEO 101 12 Intro to Physical Geology	0	33	
	GEO 101 13 Intro to Physical Geology	0	32	
	GEO 101 14 Intro to Physical Geology	0	34	

Faculty Analysis Courses Data - Assessment 2015

Core Theme 3, Objective 1 Indicator of Achievement A:

Instructor	Course	Credits	Enrolled	Core Theme 1, Objective 2, Indicator of Achievement B: Distance Delivery
	GEO 101 15 Intro to Physical Geology	0	27	
	GEO 101 17 Intro to Physical Geology	0	30	
	GEO 101 18 Intro to Physical Geology	0	31	
	GEOE 406 01 Geomorphology-Photogeology	3	5	
	GEOE 406 11 Geomorphology-Photogeology	0	5	
	GEOE 591 04 Special Topics	3	5	
	GEOE 591 06 Special Topics	3	1	
	GEOE 591 14 Special Topics	0	5	
	GEOE 599W 04 Thesis Research	3	1	
Mary M MacLaughlin				
	GEOE 104 01 Intro To Geol Engineering	1	13	
	GEOE 490 02 Undergraduate Research	1	2	
	GEOE 541 01 Adv. Eng. Geology	3	5	
	GEOE 541 11 Adv. Eng. Geology	0	5	
	GEOE 590W 02 Graduate Research	3	1	
	GEOE 591 08 Special Topics	2	1	
	GEOE 599W 02 Thesis Research	5	1	
Mary Sutherland				
	GEO 291 01 Special Topics	3	11	
	GEOE 591 09 Special Topics	3	2	
Scott Rosenthal				
	GEOE 499W 01 Geological Eng. Design Project	3	6	

Dr. Christopher H. Gammons

Tenured Full Professor
Department of Geological Engineering

Education:

B.S. Geology, Bates College (Lewiston Maine) 1980
Ph.D. Geochemistry and Mineralogy, The Pennsylvania State University, 1988

Work Experience:

Montana Tech	Full Professor (2003-present)
McGill University, Montreal	Sabbatical Leave (2004-2005)
Montana Tech	Tenure (2003)
Montana Tech	Associate Professor (1999-2003)
Montana Tech	Assistant Professor (1997-1999)
McGill University, Montreal	Research Associate/Faculty Lecturer (1993-1996)
Swiss Institute Technology, Zurich	Research Fellow (1992-1993)
Monash Univ., Melbourne, Australia	Research Fellow (1989-1992)
Penn State Univ.	Graduate Student (1982-1988)
The Anaconda Minerals Company	Exploration Geologist (1980-1982)

Professional Registrations and Licenses:

Professional Geologist (1999-present) State of Wyoming

Professional Affiliations:

The Geochemical Society
Society of Economic Geologists
American Water Resources Association
Tobacco Root Geological Society

Honors and Awards:

Montana Tech Distinguished Researcher Award (2002, 2012)
Montana Tech Rose and Anna Busch Faculty Achievement Award (2009)
AGU Editors' Citation for Excellence in Refereeing for Water Resources Research (2005)

Funded Grants, 2002-2013 (partial list: grants less than $50,000 are not shown)

Parker S, Gammons CH, Metesh JJ, RUI and MRI: Acquisition of a Picarro Carbon Isotope Analyzer. NSF-Major Research Instrumentation $186,000 (2013).

McGlynn B, Dore J, McDermott T, Gammons C, Linking microbial processes to trace gas fluxes via hydrologic controls on soil chemistry in a forested ecosystem. NSF-ESPCoR, $58,000 (2012).

Gammons C., and Parker S., Judith Mountains acid rock drainage characterization. US-BLM $71,000 (2011-2013)

Gammons C., Biogeochemical cycling of arsenic in Warm Springs Ponds. British Petroleum/Atlantic Richfield, $95,000 (2010-2012)

Parker S., Gammons C., and Hauer R. Stable isotopes of dissolved oxygen as tracers of chemical and biological processes in groundwater. NSF-EAR0739054, $177,297 (2008-2010)

Gammons C. Vertical gradients in biogeochemistry of flooded mine shafts in the Butte, Montana flooded mine complex. EPA-DOE-MWTP, $50,000 (2005-2006)

Gammons C. Geochemistry and isotopic composition of H_2S-rich water in flooded underground mine workings, Butte, Montana. EPA-DOE-MWTP, $60,000 (2003-2004)

DeGrandpre M., Moore J., Gammons C. An autonomous freshwater pH sensor: Development and applications. NSF: Hydrological Sciences Division, $300,000 (2003-2004)

Gammons C. Investigations into the origin of diel cycling of heavy metals in streams. EPA-EPSCoR $280,000 (2002-2005)

Gammons C. Subaqueous pyrite oxidation and stable isotope geochemistry of an acidic pit lake. EPA-DOE-MWTP, $50,000 (2002-2004)

Publications (selected from 82 journal publications) Underlined names are **student coauthors**

Williams G.P., Petteys K., Gammons C.H., Parker S.R. (2015) An investigation of acidic head-water streams in the Judith Mountains, Montana, USA. *Applied Geochemistry* v. 62, 48-60.

Tucci N.J., Gammons C.H. (2015) Influence of copper recovery on the water quality of the acidic Berkeley Pit lake, Montana, USA., *Environmental Science and Technology* 49, 4081-4088.

Gammons CH, Henne W, Poulson SR, Parker SA, Johnston T, Dore J, Boyd E (2014) Stable isotopes track biogeochemical processes under ice cover in a shallow, productive lake. *Biogeochem.* 120, 359-379.

White J., Gammons C.H., Zieg G.A. (2014) Paragenesis of cobalt and nickel in the Black Butte shale-hosted copper deposit, Belt Basin, Montana, USA. *Mineralium Deposita*, 49, 335-351.

Gammons CH, Pape B, Parker SR, Poulson SR, Blank C (2013) Geochemistry, water balance, and stable isotopes of a clean pit lake at an abandoned tungsten mine, Montana. *Appl.Geochem.*36, 57-69.

Gammons CH, Brown A, Poulson SR, Henderson T (2013) Using stable isotopes (S, O) of sulfate to track contamination of the Madison karst aquifer from coal mine drainage. *Appl.Geochem.* 31, 228-238.

Nimick DA, Gammons CH, Parker SR (2011) Diel biogeochemical processes and their effect on the aqueous chemistry of streams: A review. *Chemical Geology,* 283, 3-17.

Gammons CH et al. (2011) Diel cycling and stable isotopes of dissolved oxygen, dissolved inorganic carbon, and nitrogenous species in a stream receiving municipal sewage. *Chem. Geol.,* 283, 44-55.

Smith MG, Parker SR, Gammons CH, Poulson SR, Hauer FR (2011) Tracing dissolved O_2 and dissolved inorganic carbon stable isotope dynamics in the Nyack aquifer: Middle Fork Flathead River, Montana, USA. *Geochimica Cosmochimica Acta* 75, 5971-5986.

Gammons CH, & 4 others (2010) Geochemistry and stable isotope investigation of acid mine drainage associated with abandoned coal mines in central Montana, USA. *Chemical Geology* 269, 100-112.

Gammons CH, Snyder DM, Poulson SR, Petritz K (2009) Geochemistry and stable isotopes of the flooded underground mine workings of Butte, Montana. *Economic Geology* 104, 1213-1234.

Gammons CH, Nimick DA, Parker SR, Snyder DM, McCleskey RB, Amils R, Poulson SR (2008) Photo-reduction fuels biogeochemical cycling of iron in Spain's acid rivers. *Chem. Geology* 252, 202-213.

Gammons CH, Grant TM, Nimick DA, Parker SR, DeGrandpre MD (2007) Diel changes in water chemistry in an arsenic-rich stream and treatment-pond system. *Sci. Total Environ.* 384, 433-451.

Gammons CH, Poulson SR, Pellicori DA, Roesler A, Reed PJ, Petrescu EM (2006) The hydrogen and oxygen isotopic composition of precipitation, evaporated mine water, and river water in Montana, USA. *Journal of Hydrology* 328, 319-330.

Gammons CH et al. (2005) Diel behavior of Fe and other heavy metals in a mountain stream with acidic to neutral pH: Fisher Creek, Montana, USA. *Geochimica et Cosmochimica Acta* 69, 2505-2516.

Courses Taught: Physical Geology, Intro to Field Geology, Mineralogy and Petrology, Field Geology and Geophysics, Field Hydrogeology, Metallic Ore Deposits, Hydrogeochemistry, Acid Rock Drainage, Isotope Geochemistry, Montana Geology, Advanced Topics in Economic Geology

URP Mentorships: > 20 Undergraduate Research Projects supervised, 1998 to present

Graduate Committees: > 50 Graduate student M.S. projects supervised, 1997 to present

Service: Head of Department of Geological Engineering (August 2013 to present)

Montana Tech: Collegiate Review Committee, Research Advisory Committee (Seed Grant and Distinguished Researcher Award Subcommittees), Salary Committee

Scientific Advisor: Butte Science Mine Museum, Clark Fork Watershed Education Committee

Dr. Mary M. MacLaughlin
Tenured Full Professor
Department of Geological Engineering

Education:

B.Geo-E. (1988)	University of Minnesota – Minneapolis	Geological Engineering
M.S. (1989)	University of California at Berkeley	Civil Engineering
Ph.D. (1997)	University of California at Berkeley	Civil Engineering

Professional Registrations and Licenses:

EIT (1988)	Minnesota (#13757-T)

Work Experience:

Montana Tech	Full Professor (1996-present)
NIOSH Spokane Research Lab	Research Consultant (2001-2009)
University of California at Berkeley	Graduate Student Instructor, Research Assistant (1989-1996)
U.S.D.A. Forest Service	Civil/Geotechnical Engineer (1989-1993, summers)

Professional Affiliations:
American Rock Mechanics Association

Honors and Awards:
U.S. Council on Undergraduate Research Geosciences Div., Undergrad Research Mentor Award (2014)
Montana Tech Faculty Merit Award (2014)
Montana Tech Distinguished Researcher Award (2006)
Rose and Anna Busch Faculty Achievement Award, Montana Tech (2002, 2005, 2008)

Funded Grants 2006-2015:
MacLaughlin, M.M. and Wang, H.F., Demonstration of the Ability of Distributed Fiber Optic Sensing Technologies to Enhance Mine Safety through Distributed Monitoring of Ground Deformation, Temperature, & Dynamic Events, CDC – NIOSH Office of Mine Safety and Health Research, $314,331 (2014-2016).
MacLaughlin, M.M. and Smith, L.S., and Smith, D.S., MRI: Acquisition of a Shake Table for Research on Seismic Stability of Rock Masses, NSF, $314,012 (2014-2016).
Wartman, J. (originally @ Drexel University, now @ University of Washington) and MacLaughlin, M.M., NEESR-CR: Seismically Induced Rock-Slope Failure: Mechanisms and Prediction, NSF, $934,112 total with $304,451 to Montana Tech (2010-2014).
Wang, H., MacLaughlin, M.M., and Murdoch, L., Collaborative Research: Fiber-Optic Strain Monitoring of Rock Masses in Large Underground Facilities, NSF, $877,914 total with $145,332 to Montana Tech (2009-2013).
MacLaughlin, M.M. and Reichhardt, D.K., MRI: Fiber Optic & Tiltmeter Systems for Measuring Deformations in Deep Underground Facilities, NSF, $488,776 (2008-2009).
MacLaughlin, M.M. and Hudyma, N., RUI: Engineering Characterization of Rock-Like Materials with Large Voids, NSF, $213,156 (2005-2008).

Publications (82 publications, mostly conference papers, removed due to 2-page limitation):
Smith, S.E., MacLaughlin, M.M., Adams, S.L., Wartman, J., Applegate, K., Gibson, M., Arnold, L., and Keefer, D. (2014). Interface Properties of Synthetic Rock Specimens: Experimental and Numerical Investigation, *ASTM Geotechnical Testing Journal* 37:5 20 pp.
Adams, S.L., MacLaughlin, M.M., Berry, K.G., McCormick, M.L., and Berry, S.M. (2014). Three-Dimensional Roughness Characterization of Rock Joints using Laser Scanning and Wind Diagrams, *Proceedings of the 48th U.S. Rock Mechanics Symposium*, Minneapolis, MN, Paper 14-7454 (10 pp).

Gage, J.R., Fratta, D., Turner, A.L., MacLaughlin, M.M., and Wang, H.F. (2013). Validation and implementation of a new method for monitoring in situ strain and temperature in rock masses using fiber-optically instrumented rock strain and temperature strips, *International Journal of Rock Mechanics and Mining Sciences* 61(July):244-255.

Hudyma, N., Bathini, R.K., Harris, A. and MacLaughlin, M.M. (2012). Mapping surface vesicles of basalt specimens using laser scanning, *Proceedings of the 2012 GeoCongress*, Oakland, CA.

MacLaughlin, M., Berry, K.G., and Hudyma, N. (2011). Unconfined compressive strength of 4-inch plaster cubes containing large voids, *Journal of the Nevada Water Resources Association* 6(1):406-416.

Jespersen, C., MacLaughlin, M., and Hudyma, N. (2010). Strength, deformation modulus and failure modes of cubic analog specimens representing macroporous rock, *International Journal of Rock Mechanics and Mining Sciences* 47:1349-56.

Sherman, C.S., MacLaughlin, M.M., Link, C.A. and Hudyma, N. (2009). Characterizing internal macropores using cross-specimen acoustic tomography: initial two-dimensional results, *Proceedings of the 3rd Canada-US Rock Mechanics Symposium & 20th Canadian Rock Mechanics Symposium*, Toronto, Canada.

MacLaughlin, M.M., and Doolin, D.M., (2006). Review of Validation of the Discontinuous Deformation Analysis (DDA) Method, *International Journal for Numerical and Analytical Methods in Geomechanics*, 30/4:271-305.

MacLaughlin, M.M., and Sitar, N., editors (2005). *Proceedings of the 7th International Conference on Analysis of Discontinuous Deformation (ICADD-7)*, Honolulu, Hawaii, 287 pp.

Sitar, N., MacLaughlin, M.M., and Doolin, D.M. (2005). Influence of Kinematics on Landslide Mobility and Failure Mode, *ASCE Journal of Geotechnical and GeoEnvironmental Engineering*, 131/6:16-728.

MacLaughlin, Mary M. and Richard L. McNearny, editors (2004). *Proceedings of the 39th Symposium on Engineering Geology & Geotechnical Engineering*, Butte, Montana, 374 pp.

Clapp, Kathryn K., Larry N. Smith, Mary M. MacLaughlin, and Carlyle R. Miller (2004). *Geologic Map of the Columbia Mountain Area, Northwest Montana,* Montana Bureau of Mines and Geology Open File Report #487.

MacLaughlin, Mary M., David M. Doolin, and Elizabeth A. Berger (2003). A Decade of DDA Validation, Invited Keynote Lecture, *Proceedings of the Sixth International Conference on the Analysis of Discontinuous Deformation (ICADD-6),* Trondheim, Norway, pp. 13-31.

MacLaughlin, Mary M. Nicholas Sitar, David M. Doolin, and Tracy S. Abbot (2001). Investigation of Slope Stability Kinematics Using Discontinuous Deformation Analysis, *International Journal of Rock Mechanics and Mining Sciences,* vol. 38/5, pp. 753-762.

URP mentorships: supervised 38 undergraduate research projects, most funded by Tech's URP

Graduate Committees: supervised 16 M.S. students with completed degrees (1 Mining Eng.; 2 General Eng./Civil Eng. Option; 13 Geosciences/Geological Eng. Option), currently supervising 7 M.S. students in progress (all Geosciences/Geological Eng. Option), served on committees for 23 M.S. students in other programs (7 General Eng., 5 Geophysical Eng., 4 Mining Eng., 4 Petroleum Eng., 3 Geosciences/Geology Option).

Service (selected activities):

Head of Department of Geological Engineering (July 2009 to July 2013)

Invited proposal reviewer for National Science Foundation, panels and ad hoc (2000, 2002-2015)

Member, American Rock Mechanics Association (ARMA); Board of Directors 2009-2015

Montana Tech Undergraduate Research Committee (member 2004-2013, chair 2009- 2013); Merit Committee (development of guidelines 2008-09, applicant evaluation 2011-2013); Faculty Senate (1998-2000, 2001-2003)

Volunteer for kids' horseshow and rodeo at the Jefferson County Fair 2008-present

Dr. Glenn D. Shaw
Associate Professor
Department of Geological Engineering

Education:

B.S. Engineering Geology, Brigham Young University, 1997
M.S. Geological Engineering, University of Utah, 2000
Ph.D. Environmental Systems, University of California, Merced, 2009

Work Experience:

Montana Tech	Associate Professor (2014-present)
Montana Tech	Assistant Professor (2010-2014)
Montana Bureau of Mines and Geology	Assistant Research Hydrogeologist (2009-2010)
U.S. Forest Service	Air Quality Specialist (2009-2009)
University of California, Merced	Teaching Fellow (2005-2009)
University of California, Merced	Graduate Research Assistant (2004-2008)
University of California, Merced	Research Associate (2003-2004)
CH2M HILL	Geological Engineer (2001-2003)
AMEC Earth & Environmental	Geologist (200-2001)
University of Utah	Graduate Teaching Assistant (1997-1999)
Brigham Young University	Undergraduate Teaching Assistant (1995-1997)

Professional Affiliations:

American Water Resources Association
The Geochemical Society
American Geophysical Union

Honors and Awards:

Montana Tech Faculty Merit Award (2014-2015)
U.S. Forest Service Chief's Excellence in Research Applications Award (2012)
University of California, Merced Outstanding Environmental Systems Ph.D. Dissertation (2009)

Funded Grants, 2011-Present

Shaw, G. Stream ecological integrity monitoring at Grant-Kohrs Ranch relative to Clark Fork restoration and remediation. National Park Service $80,500 (2015).

Parker S, Gammons CH, Metesh JJ, RUI and MRI: Acquisition of a Picarro Carbon Isotope Analyzer. NSF-Major Research Instrumentation $186,000 (2013).

Shaw, G. Evaluation of hydrological function and riparian health of Johnson Creek to develop management options. National Park Service $40,000 (2011).

Shaw G., Gammons, C. Establishing a Water and Solute Budget in Georgetown Lake. Montana Tech Research Assistant Mentorship Program $6060 (2013).

Gammons, C., Shaw, G. Modeling groundwater flow in the upper plate bedrock aquifer of the Tuscarora Mountains. Newmont Mining Corporation$48,387 (2010).

Shaw, G. Using 222Rn and isotopic tracers trace groundwater-lake interactions. Montana Water Center $10,622 (2011).

Ewing, S., Shaw, G., Brookshire, J., Gammons, C. Jones, C., Stoy, P. Long-term water balance and nitrate biogeochemistry in cultivated alluvial landscapes of central Montana (Upper Missouri/High Plains ecoregions). NSF EPSCoR $10000 (2012).

Shaw, G. Monitoring the Response of Groundwater Recharge to Climactic Variation in the Headwaters of the Boulder River, Montana. Montana Tech Seed Grant $5000 (2011).
Shaw, G. Characterizing Groundwater Inflows and Potential Septic Effluent Using Novel Tracers in Georgetown Lake. Montana Tech Research Assistant Mentorship Program $5500 (2011).

Publications (Student authors underlined)

Mitchell KL, Shaw GD, Gammons CH (In Revisions) Isotope water balance in a structurally-controlled lake. *Hydrogeology Journal*.
Schweizer D., Cisneros R., Shaw G. (in Revisions) Correlation and agreement between mobile and stationary PM2.5 monitors during field operation. *Atmospheric Pollution Research*.
Liu F., Conklin MH, Conrad ME, Shaw G. (In Revisions) Controls of isotopic composition in stream water and groundwater and hydroclimatic implications, Merced River, Sierra Nevada, California. *Journal of Geophysical Research—Atmospheres*.
Cisneros R., Schweizer D., Preisler H., Bennett DH, Shaw G., Bytnerowicz A. (2014) Spatial and seasonal patterns of particulate matter less than 2.5 microns in the Sierra Nevada Mountains, California. *Atmospheric Pollution Research*. 5, 581-590.
Shaw G., Conklin MH, Nimz GJ, Liu F. (2014) Groundwater and surface water flow to the Merced River, Yosemite Valley, California: 36Cl and Cl- Evidence. *Water Resources Research*. 50(3), 1943-1959.
Shaw G., Cisneros R., Schweizer D., Sickman J., Fenn M. (2013) Critical loads of acid deposition for wilderness lakes in the Sierra Nevada (California) estimated by the steady state water chemistry model. *Water, Air, and Soil Pollution*. 225:1804.
Shaw G., White E., Gammons C., (2013) Characterizing groundwater-lake interactions and its impact on lake water quality. *Journal of Hydrology*. 492. 69-78.
Abdo G., Butler J., Myse T., Wheaton J., Snyder D., Metesh J., Shaw G. (2013) Hydrogeologic Investigation of the Beaverhead River Study Area. *Groundwater Investigations Program, Montana Bureau of Mines and Geology Open File Report*. 132 p.
Shaw G. White E., (2013) Nutrients and Groundwater-Lake Interactions at Georgetown Reservoir, MT. *Montana Department of Environmental Quality Report*. 40 p.
Shaw G. (2011) Water Quality Review: Sierra Nevada (2011) Lake Monitoring and Critical Load Assessment. *U.S. Forest Service Region 5 Air Quality Program*. 32 p.

Courses Taught: Physical Geology, Hydrogeology for Engineers, Groundwater Flow Modeling, Contaminant Transport, Field Hydrogeology, Advanced Hydrogeology

URP Mentorships: 6 Undergraduate Research Projects supervised, 2011 to present

Graduate Committees: 17 Graduate student M.S. projects supervised, 2010 to present

Service:

Montana Tech: Faculty Senate (2011 to present); Graduate Council (2010 to present); Sloan Scholarship Committee (2012 to present; Graduate School Representative search committee (2014); Sloan Scholar Mentor (2015 to present); committee member on 47 graduate student thesis committees (2010 to present)
Boy Scouts of America: Troop 1618 committee member (2015 to present); Troop 1618 assistant scout master (2011 to present)
KBMF Community Radio Station: Volunteer dj (2015 to present)

Larry N. Smith

Tenured Associate Professor
Geological Engineering

Education:

Ph.D., Geology, University of New Mexico, 1988
M.S., Geology, University of New Mexico, 1983
B.S., Earth Science, Geology, University of California, Santa Cruz, 1977

Work Experience:

Denmark Technical University	Sabbatical Leave (Jan-May 2016)
Montana Tech	Associate Professor (2012- present)
Montana Tech	Assistant Professor (Jan 2009-2012)
Montana Tech	Research Geologist Montana Bur. Mines Geology (2008-2009)
Montana Tech	Associate Research Professor, MBMG (1999-2007)
Montana Tech	Assistant Research Professor, MBMG (1993-1999)
Shell Oil Company	Exploration Geologist, Houston, TX (1988-1993)

Professional Affiliations:

Geological Society of America
American Association of Petroleum Geologists
American Quaternary Association
Canadian Quaternary Association
Tobacco Root Geological Society

Honors and Awards:

Montana Tech Merit Award (2014)
Montana Tech Rose and Anna Busch Teaching Award (2011, 2014)
Montana Tech Distinguished Researcher (2007)

Funded Grants:

Smith, LN: Geologic mapping of portions of the Cabinet, Heron, and Smeads Bench 7.5′ Quadrangles, Sanders County, northwestern Montana: US Geological Survey National Cooperative Geologic Mapping Program $17,500 (2015-2016)

MacLaughlin, M., Smith, LN, Smith, DB: Acquisition of a Shake Table for Rock-Oriented Novel Geotechnical Experimental Research (STRONGER): National Science Foundation (NSF) CMMI – Major Research Instrumentation $293,712 (2014-2016)

Courses Taught:

Physical Geology, Introduction to Field Geology, Sedimentology and Petroleum Geology, Sedimentology-Stratigraphy Lab, Geomorphology-Photogeology, Field Geology, Geology of the western U.S., GIS Applications in Natural Resources

Graduate Students Advised:

Brewer, Mandy– (2015-present); Spinazola, Vincent– (2015-present); Welk, Emily– (2014–present); Vineyard, Michael (2014–present); Sherimkulova, Asel; Rhyne, William; Hanley, Mike; Croft, Tyler; Oladeji, Lola

Graduate Committee membership:

(13) M.S., (3) Ph.D.

Selected Publications: *–Student co-authors underlined*

Madison, J.P., LaFave, J.I., Patton, T.W., Smith, L.N., and Olson, J.N., 2014, Groundwater resources of the Middle Yellowstone River area: Treasure and Yellowstone counties, Montana Part A*—Descriptive Overview and Water-Quality Data: Montana Bureau of Mines and Geology Montana Ground-water Assessment Atlas 3, 82 p.

Smith, L.N., 2011, Sedimentary record of Glacial Lake Missoula along the Clark Fork River from Ninemile to the Flathead River, Montana: Northwest Geology, v. 40, p. 125–136.

Smith, L.N., and Croft, T.O., 2015, Sequence stratigraphy, subsurface mapping, and correlation of the Lower Cretaceous Bow Island Formation, north-central Montana, *in*, Bingle-Davis, M., ed., Cretaceous Conference: Evolution and Revolution: Wyoming Geological Association 68th Annual Field Conference Guidebook, p. 7-21.

Smith, L.N., and Gibson, R.I., eds., 2011, The Superior Area and Other Papers: Northwest Geology, v. 40, 162 p.

Smith, L.N., and Hanson, M.A., 2014, Sedimentary record of Glacial Lake Missoula along the Clark Fork River from deep to shallow positions in the former lakes: St. Regis to near Drummond, Montana, *in* Shaw, C.A., and Tikoff, B., eds., Exploring the Northern Rocky Mountains: Geological Society of America Field Guide 37, p. 51-63.

Smith, L.N., and McDonald, K., 2015, Road log: Regional geology and glacial geology of the Helmville to Lincoln area, Powell and Lewis and Clark counties, Montana: Northwest Geology, v. 44, p. 233–238.

Smith, L.N., Christensen, S.B., and Hotaling, A.J., 2012, 3D outcrop mapping by photogrammetric methods–Assessing depositional and erosional events in Glacial Lake Missoula: Proceedings of the Engineering Geology and Geotechnical Symposium: University of Nevada, Reno, Nevada.

Smith, L.N., LaFave, J.I., and Patton, T.W., 2013, Groundwater Resources of the Lolo-Bitterroot Area: Mineral, Missoula, and Ravalli Counties, Montana, Part A: Montana Bureau of Mines and Geology, Ground-Water Assessment Atlas No. 4, 88 p.

Vineyard, M., Sherimkulova, A., Welk, E., Eastman, K., Hagan, T., Thomson, C., Smith, L.N., Chambers, M., Machinal, M., Mack, A., and Hofland, N., 2015, Glacial geology and geomorphological features of the Lincoln area, Lewis and Clark and Powell counties, Montana: Northwest Geology, v. 44, p. 47–54.

Institutional and Professional Service in the Last Five Years:

Curriculum Review Committee, Montana Tech, Member (2010–2015) Chair (2014-2015)
Member, Chancellor's Advisory Committee, Montana Tech (2006–2008)
Chair, Rose and Anna Busch Selection Committee, Montana Tech (Spring 2015)
Board member, Tobacco Root Geological Society (2000–present)
Publications coordinator (2004–present)
Referee for community and club hockey games
Member, Butte Citizens for Preservation and Revitalization (Butte CPR)

Diane Wolfgram, Ph.D.
Tenured Professor
Department of Geological Engineering

Education:
Ph.D., Geology, University of California, Berkeley, 1977
M.A., Geology, University of California, Berkeley, 1974
B.S., Geological Engineering with Honors, South Dakota School of Mines and Technology, 1962

Work Experience:

1999-Present	Professor of Geological Engineering (with tenure), Montana Tech
1994-1999	Associate Professor of Geological Engineering, Montana Tech
1992-1994	Assistant Professor of Geological Engineering, Montana Tech

Other Related Work Experience:

1996-2009	Head, Department of Geological Engineering
2006-2009	Head, Department of Mining Engineering
1985-1991	President and Principal Geologist, Roche Jaune Exploration, Inc.
1982-1984	Project Geologist, Anaconda Minerals Company
1980-1981	Staff Geologist, Anaconda Minerals Company
1978-1979	Mine Geologist, Anaconda Minerals Company

Professional Registration and Licenses:
Professional Engineer (Mining/Minerals), Montana, No. 18394
Professional Geologist, California, No. 5956

Professional Affiliations:
Fellow, Society of Economic Geologists
Founding Governor, Link 178 of the Order of the Engineer
25-Year Member, Society for Mining, Metallurgy, and Exploration
Member, Geological Society of America (Cordilleran Section)

Funded Grants: None in past 5 years

Publications:
Gammons C.H. and Diane Wolfgram. (1999) Transport of gold by H_2S-rich oil field waters, and the origin of Carlin-type deposits. Chinese Science Bulletin 2.
Turner, A. R., Wolfgram, D., & Barnes, S. J. (1985) Geology of the Stillwater County sector of the JM Reef, including the Minneapolis Adit. Montana Bureau Mines Geol., Spec. Publ, (92), 210-230.

Courses Taught:
Mining Geology, Subsurface Methods in Petroleum Geology, Structural Geology for Engineers, Mineralogy and Petrology, Senior Design, Geology of California

Graduate Committees:
Five (3 completed, 2 in progress)

Service:
Collegiate (Promotion and Tenure) Evaluation Committee 2010-2013 (Chair in 2011-2012).
Women's Auxiliary to A.I.M.E Scholarship Award Committee 2011-Present

APPENDIX

Geological Engineering Department – Guidelines for Tenure and Promotion

Faculty seeking promotion and tenure in the Department of Geological Engineering must follow all of the policies set forth in the Montana Tech Faculty & Staff Handbook (FSH). Each candidate is evaluated for each of the following areas: Teaching, Research, Service, and Progress toward Terminal Degree. The FSH lists items that faculty may use to demonstrate achievements in these areas, but does not specify exactly "how many" or "what level" is deemed satisfactory, because those things vary from department to department across campus.

The following guidelines were developed for the Department of Geological Engineering by a committee consisting of a subset of the Department faculty. They should be viewed as minimum requirements for tenure and promotion for faculty who carry a full teaching load. It is hoped that faculty seeking tenure and promotion will exceed these criteria. A candidate who has negotiated a lower-than-average teaching load will be held to a higher standard for research and/or service than the criteria listed below, commensurate with allocation of time. Conversely, faculty who have higher-than-average teaching loads and demonstrate excellence in teaching may be considered for tenure and promotion if they fall slightly below the listed criteria for research and/or service. Such special cases will need to be evaluated on a person by person basis.

Table 1. Minimum Criteria for Promotion to Associate Professor

According to the FSH: "the rank of Associate Professor designates those who have achieved considerable expertise in research, teaching and service and are making a significant contribution in their field. Competence and accomplishment in all areas of evaluation are necessary for promotion to the rank of Associate Professor". The following table outlines current Department standards in each evaluation area.

Teaching	Predominantly neutral or positive student evaluations demonstrating that the candidate is knowledgeable in the subject matter, is well-prepared in the classroom, and displays both concern and respect for the students' welfare and quality of education. We are currently defining "neutral to positive" as average values for the relevant questions on the standard Montana Tech course evaluation form in the range of 3 to 3.5. Service courses are expected to have average values that fall near the lower end of this range, and elective courses near the higher end.
Research	At minimum, the candidate must satisfy either of the following: • At least one peer-reviewed article in a journal with moderate to high impact factor (JIF > 1) based on research performed or published since becoming a faculty member in the Dept. of Geological Engineering, or • At least one other refereed or non-refereed publication (e.g., conference proceedings paper, abstract presented at a national or international conference, book chapter, short course, etc.) on average for each year of employment at the tenure-track level. In addition, it is expected that each candidate will have submitted at least two grant proposals to external funding agencies by the time of the application.

Service	Minimum requirements include membership on at least one University committee, supervision of at least 1 graduate student (MS degree ideally completed by time of application) and involvement of undergraduate students in research. The candidate is expected to treat other campus faculty and administrative personnel with an appropriate level of professional courtesy and respect.
Terminal Degree	No promotion without completion of a doctorate in geological engineering or a related field.

Table 2. Minimum Criteria for Tenure

According to the FSH: "Tenure is awarded for quality of current professional performance and promise for such future performance, not merely for completing a certain length of service". It is important that the candidate can demonstrate that he or she has become an *increasingly* valuable member of the Department. This table summarizes current Department standards for tenure:

Teaching	Consistently positive student evaluations are needed for award of tenure. The candidate must demonstrate through student evaluations and letters or surveys from past students that he or she is highly effective at communicating course content that is both rigorous and relevant to the students' degree program. We currently define "consistently positive" as average values of 3.5 to 4 for the relevant questions on the standard Montana Tech course evaluation form.
Research*	At minimum, candidate must satisfy either of the following: • At least two peer-reviewed journal articles based on research performed or published since becoming a faculty member in the Department of Geological Engineering at Montana Tech, or • At least one peer-reviewed journal article combined with an average of at least one non-refereed publication (e.g., conference proceedings paper, abstract presented at a national or international conference, book chapter, short course, etc.) per year for each year of employment at the tenure-track level. In addition, it is mandatory that the candidate will have shown persistent activity in terms of writing of external research grants. Given the current low rate of success for proposals to federal agencies, the Department currently has no minimum criteria in terms of number of proposals accepted or dollars funded.
Service	Significant service on multiple campus committees and active service to the community and/or profession are required. Involvement in undergraduate and graduate student advising is also mandatory. For example, it is expected that a candidate will have supervised and graduated at least 3 M.S. students by the time he or she applies for tenure. In some cases, a steady stream of successful undergraduate research projects may be accepted in lieu of M.S. student supervision.
Terminal	No award of tenure without completion of a doctorate in geological engineering or a

Degree	related field.

*NOTE: To facilitate external peer review, the candidate for tenure shall provide names and contact information of three professional colleagues who are not employed by Montana Tech and who are well-qualified to provide a written review of the candidate's research portfolio. If there is any question whether the candidate has achieved the research performance standards listed above, the department head will secure at least one external review from those named on the list, and incorporate the review into the evaluation of the candidate's research performance. Along with a copy of the candidate's full tenure application portfolio to provide context for the review, the external reviewer will be given a copy of the current tenure/promotion standards for the Department of Geological Engineering and will be asked to base their evaluation of the research component of the portfolio on the standards for tenure listed in that document.

Table 3. Minimum Criteria for Promotion to Full Professor

As stated in the Montana Tech Faculty-Staff Handbook, "the rank of Professor is reserved for those who have reached the top of their profession. In order to be promoted to the rank of Professor, it shall be necessary for a candidate to demonstrate excellence in two of three areas evaluated (teaching, research and service). Good effort and accomplishment must be demonstrated in the third area." The criteria listed below are current Departmental benchmarks for an "excellent" ranking in each of these evaluation areas.

Teaching	The candidate must document overall excellence in teaching through examples of at least three of the following: • Letters from previous students, • Letters of support from colleagues with knowledge of the candidate's performance in this area, • Evidence of having an active role in development/improvement of curricula, • Staying current in course content, • Exploring new technology and/or teaching methodologies, and/or • Maintaining an average of 4 or higher in the responses to relevant questions on the standard Montana Tech course evaluation form.
Research	At minimum, the candidate must satisfy either of the following: • At least three peer reviewed journal articles and/or textbooks based on research performed or published since becoming a faculty member in the Department of Geological Engineering at Montana Tech, or • At least two peer-reviewed journal articles and/or textbooks, combined with an average of at least one non-refereed publication (e.g., conference proceedings paper, abstract presented at a national or international conference, book chapter, short course, etc.) per year for each year of service as a faculty member at Montana Tech. For an "excellent" research ranking, the candidate must also demonstrate success in securing external funding to improve the research infrastructure of Montana Tech, and

	to support graduate and/or undergraduate research.
Service	Multiple years of service as Chair of a major campus committee, such as the Faculty Senate, and/or multiple years as Chair of the Department of Geological Engineering. An excellent record in supervision of graduate and undergraduate research *and* an outstanding level of service to the Community or Profession is also required to get a rating of "excellent" in this category. Examples of "service to the Profession" include being editor of a professional journal, multiple years as officer of a professional organization, frequent reviews of articles for technical journals or proposals for external agencies (such as NSF ad-hoc or panel reviews), or experience on a national committee or ABET review team.