FOR APPROVAL **PUBLIC** **OPEN SESSION**

TO:	Academic Affairs Committee
SPONSOR:	Amrita Daniere, Vice-Principal, Academic & Dean
CONTACT INFO:	905-828-3719, vpdean.utm@utoronto.ca
PRESENTER:	Professor Marc Laflamme
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DATE:	March 21, 2019 for March 28, 2019
AGENDA ITEM:	3

ITEM IDENTIFICATION:

Major Modification: Undergraduate Earth Sciences Program Proposal

JURISDICTIONAL INFORMATION:

Under section 5.6 of its terms of reference, the Academic Affairs Committee is responsible for "major and minor modifications to existing degree programs. All major modifications shall be reported annually for information to the appropriate body of Governing Council".

GOVERNANCE PATH:

1. **Academic Affairs Committee [For Approval] (March 28, 2019)**

PREVIOUS ACTION TAKEN:

No previous action was taken on this proposal.

HIGHLIGHTS:

The Department of Chemical and Physical Sciences (CPS) is proposing a major modification to the program requirements and learning outcomes of the existing Earth Sciences Specialist program. The modified program is designed to offer common foundational skills in Earth Sciences to our students, as well as flexibility in tailoring their program through a selection of upper year courses that will also meet the certification requirements of the Association of Professional Geologists of Ontario (APGO). The proposed modifications are in response to the recommendations from the 2017 department external review to consolidate the Geology and Earth Science specialists and include new courses that draw upon the expertise and collaboration between Earth Sciences (ERS) and other CPS discipline faculty. The latter has resulted in the creation of courses such as Geochemistry (ERS301H5) and Geophysics (ERS303H5). [Note that subsequent to the approval of this modified ERS specialist program, the current Geology

specialist program will be administratively suspended (via the submission of a separate proposal to close the program)]. This modification combined with an enriched ERS curriculum will also reduce the reliance courses from the St. George campus to meet program requirements.

The major modification will propose to increase the requirement in the ERS Specialist from 11.0 to 14.0 FCEs and will also introduce two optional pathways of courses that fall within the Geology and Environmental Geoscience streams (outlined as certification requirements by the APGO). The listed courses in the *Resources, Hazards & Tectonics* pathway correspond to the APGO's Geology stream; courses listed in the *Earth, Climate & Life* pathway correspond to the APGO's Environmental Geoscience stream. Outlining these pathway options to our students will signal a clear direction to APGO certification for those who wish to become professional Earth Scientists.

This program change was proposed in response to the increased demand for geoscientists trained in environmental issues, and for environmental scientists trained in Earth Science. The modified program will not only prepare our students for a competitive job market, as certified professionals associated with the APGO, but will also foster student learning in core issues, such as sustainability in the face of resource consumption and global climate change.

FINANCIAL IMPLICATIONS:

There are no net implications for the campus' operating budget.

RECOMMENDATION:

Be It Resolved,

THAT the proposed changes to the Specialist in Earth Science (ERSPE1465), offered by the Department of Chemical & Physical Sciences, recommended by Vice-Principal, Academic & Dean, Professor Amrita Daniere, and described in the proposal dated January 18, 2019, be approved, effective September 1, 2019.

DOCUMENTATION PROVIDED:

Major Modification Proposal: Specialist in Earth Science (ERSPE1465)

University of Toronto
Major Modification Proposal:

Significant Modifications to Existing Graduate and Undergraduate Programs

This template should be used to bring forward all proposals for major modifications to existing graduate and undergraduate programs for governance approval under the University of Toronto's Quality Assurance Process.

Program being modified:	Specialist in Earth Science (ERSPE1465)
Proposed major modification:	Significant changes to program requirements and learning outcomes in order to establish a program that grounds students in the fundamentals of Earth Science, and meets requirement of the Association of Professional Geologists of Ontario (APGO)
Department/unit (if applicable):	Department of Chemical & Physical Sciences (CPS)
Faculty/academic division:	University of Toronto Mississauga (UTM)
Dean's office contact:	Andrew Petersen Acting Vice-Dean Teaching and Learning vdteachlearn.utm@utoronto.ca Rosa Ciantar Acting Program & Curriculum Officer rosa.ciantar@utoronto.ca
Proponent:	Claudiu Gradinaru Chair, Department of Chemical & Physical Sciences cpschair.utm@utoronto.ca Paul Piunno Associate Chair, Undergraduate paul.piunno@utoronto.ca Marc Laflamme Program Advisor, Earth Science marc.laflamme@utoronto.ca
Version date:	January 18, 2019

1 Summary

Earth Sciences, a discipline within the Department of Chemical Physical Sciences at UTM is in a renewal phase, with new research laboratories, a new laboratory technician to support teaching, and new teaching laboratories slated for 2019. The central plank of this renewal is an expansion in faculty, as recommended by the recent external review of the Department of Chemical and Physical Sciences (CPS). Professor Dan Schulze has retired after 30+ years of service, and we recently hired two new faculty who started in July 2018, in Field Geology, Petrology, Geochemistry, and Volcanology (Teaching Stream, Paul Ashwell) and Applied Geophysics (Research Stream, Semechah Lui). With these new hires, and a switch to a faculty teaching rotational scheme with most upper year courses being offered in alternate years, we have introduced 12 new courses (2 in the 2017-18 calendar year, 7 in 2018-19, and 3 in 2019-20). These changes will more than double the number of Earth Science courses offered on the University of Toronto Mississauga (UTM) campus. A full Earth Science program can now be offered at UTM eliminating the requirement for ERS students to supplement their program requirements with courses offered at the St. George campus.

These new courses were part of a curriculum plan intended to both provide students with a robust and broad education in the Earth Sciences, as well as to provide students with a program of study recognized by the Association of Professional Geologists of Ontario (APGO). The APGO is the licensing and regulatory body for any person wishing to practice as a professional geologist in Ontario. Geoscience is a regulated profession, similar to engineering, medicine, and law. Practicing geoscience without a license can result in legal action or financial penalties. Registration with APGO confers the Professional Geoscientist (P.Geo) designation. For additional information please consult: https://www.apgo.net/mpower/ktoolkit/public-requirements.action

In addition to a major program modification that includes increasing required ERS Specialist credit hours from 11.0 to 14.0, we are proposing the introduction of two optional pathways of courses that fall within the Geology and Environmental Geoscience streams of the APGO.

2 Effective Date

September 1, 2019

3 Academic Rationale

We live in a world of changing climate and dwindling natural resources; no scientific discipline addresses the incumbent challenges more directly than Earth Science. Earth Sciences are relevant to a broad range of economic drivers including mining, water management, environmental protection and remediation, and energy capture and exploitation. Earth Scientists are employed by private sector resource extractors, construction companies and consultants, and by federal and provincial government regulators, as well as municipalities. The mining sector is an important part of the Canadian economy, and mineral prospecting, exploration and ultimately resource recovery is conducted by Earth Scientists. At the same time, the demand for geoscientists trained in environmental issues, and for environmental scientists trained in Earth Science, is ever more acute as environmental and global change concerns have become increasingly prominent in the decision-making processes in both the private and public sectors.

Our proposed program supports two goals of the UTM Academic Plan. In particular, our program will support Goal 1 to "inspire student success by supporting a rigorous and innovative academic environment" by focusing on "preparing students for further study, including graduate and professional programs, and the global workforce." Our students will explicitly be prepared now, for example, to join the Professional Geoscience accreditation body in Ontario, the Association for Professional Geoscientists of Ontario (APGO). Additionally, our program addresses Goal 5 of the plan to "focus on transformation and innovation to create a sustainable and cohesive community". Earth Science research and teaching address core issues of sustainability in the face of resource consumption and global climate change.

In addition, our proposed modifications to the program addresses concerns and follows recommendations made during the department external review in 2017. The reviewers recommended, among other things, that 1) the Geology and Earth Science specialists be consolidated, and 2) new courses (i.e., in geophysics and geochemistry) be established to improve the collaboration between Earth Sciences faculty and others in the department of Chemical and Physical Sciences. To this end, we have proposed two new courses: Geochemistry (ERS301H5) and Geophysics (ERS303H5). Furthermore, subsequent to the approval of the modified ERS specialist program, the current Geology specialist program will be administratively suspended (via the submission of a separate proposal to close the program).

In order to address the above discussed societal needs, UTM academic planning goals, and recommendations of the 2017 CPS external review, we propose to offer a comprehensive and modern Earth Science program at UTM. For many years we have been only able to offer ~10 Earth Science courses, which necessitated adding courses either from Geography at UTM to make up the Earth Science Specialist, Major, and Minor, and the Environmental Geology Specialist, or courses from the St. George campus to make the Geology Specialist program. With our two new faculty, and our switch to alternating courses in the upper years, we are now able to offer 12 additional courses and a full program at UTM.

The main goal of offering a greatly increased number of courses in Earth Sciences at UTM is to fulfill our program learning outcomes for the Specialist (note Majors and Minors in Earth Science will have a subset of these PLOs depending on course selection), which include:

1. Breadth & Depth of Knowledge
   - Describe the fundamental concepts of Earth Science including the origin, composition, and evolution of the Earth, and how the Earth system responds to internal and external forces, including climate change and the forces of humans.
   - Conceptualize spatial data and temporal geologic change.

2. Knowledge of Methodologies
   - Identify, describe, and classify earth materials and structures and interpret them in the context of geologic processes.
   - Analyze quantitative geologic data collected in the field and laboratory.
   - Engage in field-based experiential learning addressing proper geological technical skills (mapping, sampling, interpreting outcrop patterns, etc.)

3. Application of Knowledge
   - Apply physics, chemistry, biology, statistics, and mathematics, as appropriate, to solve geologic problems.
   - Apply geoscience knowledge to address problems affecting human society, locally and globally, including effective sustainability of the natural world and its resources, and aid in predicting and managing geological hazards.
   - Utilize course-based knowledge to inform field-based observations and interpretations.

4. Communication Skills
   - Communicate scientific information using written, oral, graphical, and electronic forms.
   - Read, critically evaluate, and produce professional papers and geologic maps.
   - Provide critical feedback through peer-review practices

5. Awareness of Limits of Knowledge
   - Recognize bias and incompleteness inherent in the geologic record
   - Apply critical thinking and self-assessment tools through research pursuits, both in the form of direct participation in hands-on research and/or via synthesis of critical review literature and research proposals.
   - Gain an appreciation for the discipline limits of knowledge through dedicated literature reviews and in-class discussions.
   - Identify large-scale issues that lie at the boundary of Earth Science discipline limits of knowledge, and provide direction on how to test these hypotheses.

6. Autonomy and Professional Capacity
   - Develop a sufficiently broad and rigorous scientific background to allow for a career or advanced study in geoscience.

- Develop the skills necessary to conduct research autonomously though writing research and/or critical literature review papers, and peer-to-peer review and criticism.

In order to meet these learning objectives, our students need to take a significant number of courses, both at the foundational level (ERS201H5, 202H5, 203H5, 211H5, 225H5, 301H5, 303H5), but also advanced courses now offered in our 300 and 400-level courses (ERS311H5, 315H5) where communication and metacognitive skills are targeted so as to produce autonomous graduates. Our current program requires only 11.0 credits, necessitated by our formerly small course offerings. Students graduating from our current program are not meeting our learning objectives, nor are they adequately prepared for employment in the Geoscience workforce. The revised program will require 14.0 credits, the minimum necessary to guarantee that our students meet the aforementioned learning objectives.

Earth Sciences is a broad field of study, requiring foundational skills in Chemistry, Math, Physics, Biology, and Statistics. In our the revised curriculum of the program, we require 9 semester-long courses in these subjects in order to prepare our students for, among other things, our newly required courses in Geochemistry (ERS301H5) and Geophysics (ERS303H5). Given the multidisciplinary nature of geological sciences, our students must be able to understand, apply, and reflect upon data generated in these other scientific disciplines.

An important additional aspirational goal of our Specialist program is to prepare our students for the job market. This requires APGO certification. The APGO was formed in the year 2000 and membership has grown rapidly to more than 2,000 since that time. As APGO has matured, it has become increasingly important for employment in Ontario. In fact, it is **not possible** to work in Ontario at any level higher than a technician without APGO status and a Professional Geoscientist (P.Geo) designation. Following multiple meetings with representatives from the APGO, it has become apparent that in the next few years, APGO certification will be required for all Earth Science jobs in Ontario. **At present, all undergraduate programs in Earth Science in Ontario (including the St George and Scarborough Campuses of UofT) offer APGO compatible Earth Science programs, except for UTM**.

Our recent graduates report that they can be hired without APGO status, but with the understanding that they will complete registration during the first year or two of their employment. A consequence will be that our graduates from the existing program will be required to complete additional undergraduate courses post-graduation. APGO membership requires completion of "knowledge requirements," along with four years of work experience. Students apply for "Geologist-in-Training" status upon graduation while they complete their work experience. APGO requires 13.5 credits in Foundation Science (Math, Physics, Chemistry, Biology, Statistics, Computer Science), Foundation Geoscience, and Advanced courses to be completed during the undergraduate program. APGO suggests students follow one of three "streams," including Geology, Environmental Geoscience, or Geophysics.

Our proposed program is designed to offer both common foundational skills to our students, as well as flexibility in tailoring their program through their choice of upper year courses. While some students will have no trouble navigating course choices on their own according to their interests, some may wish for more guidance. We also want to make the pathway to APGO

accreditation straightforward and obvious to all students, while still fulfilling our learning outcomes. Therefore, we propose to suggest students follow one of two "pathways" of courses for their 300- and 400-level course options. Our *Resources, Hazards & Tectonics* pathway would correspond to the APGO's Geology stream, and our Earth, Climate & Life pathway would correspond to the APGO's Environmental Geoscience stream. The primary benefit of this approach is to provide a clear path to APGO certification for those who wish to become professional geologists, while also accentuating aspects of our program that target some of the largest issues facing our planet today.

4 Description of the Proposed Major Modification(s)

We propose a major modification to the Earth Science Specialist program. In order to meet our newly developed learning objectives, fulfill APGO requirements, address the UTM Academic Plan, and respond to recommendations from the 2017 CPS external review, we proposed the following.

The program will be increased from 11.0 to 14.0 credits. The additional 3.0 credits are necessary to ensure that our students meet the knowledge and skill requirements of our learning outcomes, and that they fulfill the requirements for professional accreditation by the APGO. Of the additional 3.0 credits, 1.5 will come from courses in Biology and Statistics required to provide the 4.5 full credits of non-geoscience "foundation science" required by the APGO. (Due to required prerequisites, most of the courses selected to fill the foundation science requirements are first year courses.) In addition to being required by the APGO, the statistics course will support our learning outcomes under Knowledge of Methodologies and Awareness of the Limits of Knowledge, and the Biology courses will support student learning in Earth, Climate, & Life focused courses, such as Environmental Geology (ERS315H5), Paleobiology (ERS411H5), and Climate Through Time (ERS412H5).

There are two primary means by which students will enter our program: either through a geology background via ERS101H5 (Planet Earth) and ERS111H5 (Earth, Climate & Life), or from a geography standpoint via ENV100Y5 (The Environment). A minimum grade requirement of 60% is put in place to ensure students have the fundamental background required to succeed in an Earth Science program.

At the "foundational" level, in addition to the currently required ERS201H5, 202H5, 203H5, and ERS325H5, we will now require a field course (ERS225H5) which supports our learning outcome of analyzing quantitative geologic data collected in the field and laboratory. We will also require a course in Sedimentary Geology and Stratigraphy (ERS211H5), and 300-level courses in Geochemistry (ERS301H5) and Geophysics (ERS303H5) in order to satisfy learning outcomes under Student Depth and Breadth of Knowledge.

In the upper years, the program will be flexible, with students able to tailor their program based on their interests. Importantly, all of our 400-level capstone courses (ERS402H5, ERS403H5, ERS404H5, ERS411H5, ERS412H5, ERS425H5, ERS470Y5, ERS471H5, ERS472H5, ERS499H5) will include the following components directly linked to our expected DLEs: 1) a research term paper, 2) an annotated bibliography, 3) a peer-review exercise, and 4) an oral (or poster) presentation. To provide guidance for students that wish it, and to ensure APGO certification for students in the Specialist program, we will suggest two optional pathways for students to follow, along the themes of Earth, Climate & Life, and Resources, Hazards & Tectonics (please see Appendix C for proposed calendar copy). Again, the "pathways" are meant to offer directional guidance for our students, but students are welcome to pick and choose any courses between them to fulfill their own personal interests when completing the specialist program.

Lengthy discussions with representatives of the Dean's Office (UTM; most notably Rosa Ciantar, *Acting Program & Curriculum Officer* and Andrew Petersen*, Acting Vice-Dean, Teaching and Learning*) were undertaken in order to resolve the potential problem of requiring 5.0, 100-level credits, given the 6.0 credit limit for 100-level courses at UofT. All attempts were made to limit the number of required 100-level courses, however it was not possible due to three primary factors:

(1) All courses included in the modified ERS Program are based on the APGO requirements as stipulated by our governing body. Although upper-year courses (200-level and higher) can be used as valid replacements, all suitable 200+ level courses at UTM in MAT, CHM, PHY, and BIO have 100-level prerequisites. As such, we would not be fixing the issue, only masking it by requiring a 200-level course with 100-level prerequisites that the students would still need to take.

(2) When compared to a similar program offered at the St. George campus (Environmental Geosciences Specialist), the only difference in credit number, and required courses, was the inclusion of ERS101 and ERS111 in our program which adds 1.0 FCE of 100-level courses. Both of these courses serve several important purposes both within our department (Chemical and Physical Sciences) and UTM. First of all, these courses serve as initial gateways into our program given that most students at UofT have not been exposed to Earth Sciences in high school (unlike most other sciences). As such, their first exposure to our discipline is through ERS101 and ERS111. Furthermore, These courses serve as breadth courses for non-science disciplines, with ~200 students in ERS111 and >450 students in ERS101, most of which from the Humanities and Social Sciences. In many cases, students only transition into our program after experiencing these introductory courses, so if they are not included in our program, then students are not getting credit for these gateway courses.

(3) Given the lack of Earth Science teaching in High School, most of our students would not be equipped with the necessary skills to jump straight into 200-level ERS courses. Our 200-level courses teach the fundamental aspects of Earth Science, with the understanding that students have a basic background in describing the formation of different rock types,

geological and environmental systems that lead to mineral deposits, the deep history of climate and life on Earth, and how environmental catastrophes and hazards are mitigated by society. These topics are extensively covered in our 100-level ERS courses. The Environmental Geosciences Specialist does recommend JEG100H1: Introduction to Physical Geography and Earth Science as a "first-year elective" in their program, but indicates that it is not necessary for APGO accreditation.

We understand and appreciate that this is not ideal, and may lead to students requiring >20 credits in order to finish their degrees, especially if they take 6.0 FCE (or more) of 100-level courses before selecting this program of study. To help alleviate this issue, counselling will be available for all second-year students via the CPS Academic Advisor and ERS Faculty Advisor. Furthermore, given the difficulty with the number of required 100-level credits, our university outreach events (for example, Ontario University Fair, University Open House, or any of the multiple frosh-week initiatives at UTM) will directly address the importance of planning your 100-level credits accordingly, and ensure students interested in a possible ERS Specialist program consider taking 200-level courses in the Humanities or Social Sciences that do not required 100-level prerequisites. This should ensure ERS students meet all University level expectations without going over the 4-year, 20 credit goal.

The required courses of the proposed basic program are as follows:

Earth Science Specialist (14.0 Credits)

ERS101H5 – Planet Earth AND ERS111H5 – Earth, Climate & Life, OR ENV100Y5 – The Environment
CHM110H5 – Chemical Principles I AND CHM120H5 – Chemical Principles II
PHY136H5 – Introductory Physics I AND PHY137H5 – Introductory Physics II
MAT135H5 – Calculus I AND MAT136H5 – Calculus II
BIO152H5 – Intro to Evolution and Evolutionary Genetics AND BIO153H5 – Diversity of Organisms
STA220H5 – The Practice of Statistics I
ERS201H5 – Earth Materials
ERS202H5 – Dynamic Earth
ERS203H5 – Rock Forming Processes
ERS211H5 – Sedimentology and Stratigraphy
ERS225H5 – Field Methods
ERS301H5 – Geochemistry
ERS303H5 – Geophysics
ERS311H5 – Sedimentology and Basin Analysis
ERS315H5 – Environmental Geology
ERS325H5 – Field Camp

2.5 additional credits from ERS at the 300 level or higher, GGR201H5, GGR217H5, GGR276H5, JGE378H5, or JCB487H5; no more than 1.0 credits from ERS299Y5/ERS399Y5/ERS499Y5/ERS470Y5/ERS471H5/ERS472H5 or JCB487Y5 can be counted toward the specialist.

1.0 credit from ERS at the 400 level or JCB487Y5

For students with an interest in the **Earth, Climate & Life** pathway we would make the following recommendations for the 3.5 additional credits from upper year courses:
GGR201H5 – Introduction to Geomorphology
GGR217H5 – Fundamentals of Hydrology
ERS304H5 – Geological Remote Sensing
ERS312H5 – Oceanography
ERS411H5 – Paleobiology
ERS412H5 – Climate through time
ERS425H5 – Geology of North America
ERS399Y5/ERS499Y5/ERS470Y5/ERS471H5/ERS472H5, JCB487Y5 – Research

For students interested in the **Resources, Hazards & Tectonics** pathway we would make the following recommendations for the 3.5 additional credits from upper year courses:
JGE378H5 – Natural Hazards
ERS302H5 – Tectonics
ERS304H5 – Geological Remote Sensing
ERS402H5 – Advanced Structural Geology
ERS403H5 – Earthquake Seismology
ERS404H5 – Volcanology and Geothermal Systems
ERS425H5 – Geology of North America
ERS399Y5/ERS499Y5/ERS470Y5/ERS471H5/ERS472H5, JCB487Y5 – Research

Through the proposed changes to the current ERS Specialist program we will be offering a full selection of courses on the UTM campus, most in CPS. Instead of disappearing to UTSG in their 3rd and 4th years, our program students would now have the opportunity to remain at UTM to complete their program and continue to populate our courses. We expect that the format of the modified program, which is aligned with APGO certification, will significantly increase employment opportunities for our graduates. One of the anticipated results will be attracting more students to Earth Sciences at UTM.

The learning objectives of our existing program were never fully developed, however, learning objectives have been developed for individual ERS courses. In association with this program proposal, our students will now fully meet our divisional Degree-Level Expectations, as presented in Appendix A.

All our lectures are accessible to students with physical or mental health issues and accommodations are being made as the need arises/on a case-by-case basis.

5 Impact of the Change on Students

All of our current courses will continue to be offered, hence, students currently enrolled in the ERS Specialist program will not be negatively impacted by these proposed changes. In addition, second year students wanting to transition into this program can apply to the Department requesting a subject post exception. Year 2 students either within the ERS community or across the entire UTM undergraduate community, will be encouraged to attend one-on-one advising sessions with the Department Academic Counsellor and Earth Sciences Faculty Advisor. As explained above, given the difficulty with the number of required 100-

level credits, our councilors will directly address the importance of planning your university trajectory, and ensure students interested in a possible ERS Specialist program consider taking 200-level courses in the Humanities or Social Sciences that do not required 100-level prerequisites.

Students were consulted in two ways. In the summer of 2016, we assembled an email list of all students active in our five programs (Earth Science Specialist, Major, Minor, Geology Specialist, Environmental Geoscience Specialist), and invited each to complete a short on-line survey. Forty-five students responded to our survey. Students indicated the importance to them of future employment, emphasized the desire for greater choice in 300-level and 400-level course offerings and being able to complete their program entirely at UTM, and asked for increased opportunities for field work in the program. Our revised program is based largely on these requests.

After development of this proposal, we consulted students through the September 2017 meeting of the Tuzo Wilson Student Club, asking for on-the-spot as well as follow-up feedback. The proposed changes were enthusiastically received by the students, with no significant requests for changes to the program.

6 Consultation

Consultation was undertaken with the Office of the Dean Academic, UTM. In addition, discussions were held with faculty and department chairs in the Departments of Geography and Chemical and Physical Sciences. We also consulted the Office of the Registrar, UTM and all other departments (Department of Biology, Department of Mathematics and Computational Sciences) whose courses will be used toward completion of the program during the annual curriculum meetings; they had no substantive feedback and confirmed they were good with the proposed program. The proposed changes will eliminate some GGR course requirements from our Earth Science specialist program, but these courses remain options, and are recommended for the Earth, Climate & Life pathway, and therefore we anticipate little to no negative impact on the Geography programs or courses. Rather, we expect that many of our new courses can be included as options for the programs in Environmental Science and Geography. No impact on other programs are expected.

7 Resources

No other resource implications are expected. We will monitor program enrolments following the implementation of the proposed major changes and should enrolments significantly increase in ERS courses, further consultation may be required to review the required resources to accommodate growth. Two dedicated Earth Sciences teaching laboratories, which will each be able to accommodate a maximum capacity of 33 students in one room and 50 in the other, are scheduled to be completed by fall 2019. We expect these teaching spaces to address any future growth across our courses and programs.

No new agreements or modifications to existing agreements are needed.

8 UTQAP Process

The UTQAP pathway is summarized in the table below.

	Approving Body	**Approval Date**
Development/consultation within unit	Claudiu Gradinaru Chair, CPS	December 8, 2017
Consultation with Dean's office (and VPAP)	Andrew Petersen Acting Vice-Dean, Teaching & Learning	November 30, 2018
	Angela Lange Acting Vice-Principal Academic & Dean	November 30, 2018
Submission to Provost's office & Provostial Sign-Off	Susan McCahan Vice-Provost, Academic Programs	January 15, 2019
Divisional Governance Approval	UTM Academic Affairs Committee (AAC)	February 12, 2019
Reported to the Provost and included in annual report to AP&P	Committee on Academic Policy & Programs	
Ontario Quality Council—reported annually		

9 Appendix A: Proposed Learning Outcomes, and Degree-Level Expectations

For many years we have been only able to offer ~10 Earth Science courses, which necessitated adding courses either from Geography at UTM to make up the Earth Science Specialist, Major, and Minor, and the Environmental Geology Specialist, or courses from the St. George campus to make the Geology Specialist program. With our two new faculty hires, and our switch to alternating courses in the upper years, we are now able to offer a full program, which is compatible with the APGO requirements for professional certification, in Earth Science on the UTM campus. Our modified program has been designed to have our students meet or exceed our divisional Degree Level Expectations, as presented below.

Degree-Level Expectations	**Program Learning Outcomes**	**How the Program Design/Structure Supports the Degree-Level Expectations**
1. Depth and Breadth of Knowledge a. knowledge and a critical understanding of the central concepts, current methodologies and recent advances, theoretical approaches and assumptions, and intellectual history of at least one discipline b. an understanding of many of the major fields in that discipline and the relationship of the discipline to other disciplines c. a detailed knowledge of and some experience with the practice and fundamentals of research and enquiry in the discipline d. critical thinking and analytical skills inside and outside the discipline e. knowledge of central concepts from at least one other discipline.	Describe the fundamental concepts of Earth Science including the origin, composition, and evolution of the Earth, and how the Earth system responds to internal and external forces, including climate change and the forces of humans. Identify and describe the formation and accumulation of fossils, rocks, and minerals. Identify, describe, and classify earth materials and structures at multiple scales. Evaluate spatial data through the use of geological and geographic maps. Describe the major changes in Earth lithosphere, biosphere, hydrosphere and	Students will learn the basics concepts of Earth Science through completing one of two introductory courses focused on historical geology (ERS111H5: Earth, Climate, Life), or physical geology (ERS101H5: Planet Earth). Both courses include laboratory components to ensure hands-on exposure to Earth materials and processes. Core Earth Science is covered in our fundamentals courses, including ERS201H5 (Earth Materials), ERS202 (Dynamic Earth), ERS203H5 (Rock Forming Processes), ERS211H5 (Sedimentary Geology), ERS301H5 (Geochemistry) and ERS303H5 (Geophysics). All these courses include laboratory components. We also emphasize the spatial aspects of Earth Science, at scales from microscopic to hand sample to outcrop to mountain range to whole Earth. Our program emphasizes the concept of geologic time throughout – the necessity of grappling with vast history is nearly unique to Earth Science. These topics form the core of our foundational geoscience teaching.

	atmosphere through time.	
2. Knowledge of Methodologies a. an understanding of methods of enquiry or creative activity, or both, in their primary area of study.	Interpret earth materials in the context of geologic processes through the application of petrographic and hand-sample studies. Quantitatively analyze field and laboratory data.	Because of its interdisciplinary nature, Earth Science encompasses a wide range of methodologies. Students learn to identify rocks and minerals in hand specimen and thin section (optical mineralogy + petrology) in the required courses ERS201H5 and ERS203H5. The required course ERS202H5 focuses on structural geology and tectonics. Students learn strain and fabric analysis techniques, including use of the Mohr Circle. They learn to draw and interpret geologic maps (including three-point problems, fold projection, and orthographic methods) as well, developing their skills in 3-D visualization using stereo net projection methods. In the required ERS211H5 and ERS311H5, with their focus on sedimentary geology, students gain experience in grain size analysis, facies analysis (reconstruction of paleo-environment), and sequence stratigraphy. In the required ERS315H5, they learn about geological aspects of pollution and waste disposal and environmental impact and mitigation of extracting/using Earth resources. Our required courses in geophysics (ERS303H5) and Sedimentology and Basin Analysis (ERS311H5) allow students to apply methods of well-log and geophysical data (seismic, gravity, magnetic, etc.). Probably the most fundamental methodologies associated with Earth Scientists are based in field work. It is essential for students to learn to locate themselves, draw contacts, faults and other features on a geologic map, measure the strike and dip of planar features such as bedding or fold axial planes, and measure the trend and plunge of linear features such as intersection cleavages or fault slip indicators. Field skills will be introduced in the required ERS225H5 (Field Methods) and expanded upon during an extended, required two-week trip in ERS325H5 (Field Camp).
3. Application of Knowledge a. gather, review, interpret, present,	Apply physics, chemistry, biology, statistics, and mathematics, as	Field work (ERS225H5, ERS325H5) is an ideal setting in which students are able to apply their discipline-specific knowledge to Earth Science problems. Foundational knowledge gained through our required courses in mineralogy, petrology, sedimentology and

produce and critically evaluate information, arguments, assumptions, abstract concepts, hypotheses and/or creative options b. make informed judgments in accordance with the major theories, concepts, intellectual and artistic traditions, and methods of the subject(s) of study c. apply relevant concepts, principles, and techniques, both within and outside the discipline d. frame appropriate questions, solve problems, propose and test solutions e. formulate coherent lines of argument f. if applicable, produce a creative work.	appropriate, to solve geologic problems. Apply geoscience knowledge to address problems affecting human society, locally and globally, including effective stewardship of the natural world and its resources, and aid in predicting and managing geological hazards.	structural geology come together in interpreting the composition, deformation, paleo-environmental setting and geologic history of an outcrop or map area (ERS325). Students explore the impact of human activities on the Earth system in ERS315H5, with a focus on environmental geology and the Earth as an interconnected system. For example, students apply their knowledge to address groundwater flow and contamination, pollution and waste disposal, and the environmental impact of resource extraction in ERS315H5. In order to ensure that our degree level expectations are met, all of our 400-level courses will include an end-of-term paper that helps students summarize and apply their acquired knowledge.
4. Communication Skills a. express information, arguments, and analyses accurately and with clarity, both orally and in writing b. present work in a variety of formal and informal contexts in forms appropriate to the discipline c. communicate effectively to a range of audiences	Communicate scientific information using written, oral, and graphical forms. Prepare geologic data for a variety of audiences	Our program has a strong emphasis on scientific writing. Students write essays starting in their first year (ERS111H5). Students write research papers or mock grant (NSERC) proposals in a number of required courses, including ERS211H5, ERS301H5, ERS303H5, ERS311H5, and ERS315H5. In ERS211H5, students also undertake peer-review exercises in order to engage in productive criticism. Additional communication skills include the design and production of a semester long poster project that culminates with a poster session and short oral presentations in ERS202H5 and ERS311H5, both of which are program requirements. All of our 400-level courses will include the following components directly linked to DLE4: 1) an end-of-term paper that focuses on written communication, 2) a peer-to-peer review exercise to provide critical

d. use communication technologies effectively		feedback, and 3) a public presentation where students can enhance their communication skills.
5. Awareness of Limits of Knowledge a. demonstrate an understanding of the limits to their own knowledge and ability b. demonstrate an appreciation of the uncertainty, ambiguity and limits to knowledge and how this might influence analyses and interpretations	Recognize bias and incompleteness inherent in the geologic record Apply critical thinking and self-assessment tools	Earth Scientists are keenly aware of limits of their knowledge because the geologic record is inherently incomplete, a problem that grows worse the further back in geologic time we go, while physical and chemical processes erase the physical record of what came before. Further, Earth Scientists must grapple with tremendous time spans, and processes that operate either so slow as to barely be observed (e.g., exhumation and erosion of a batholith, the motion of tectonic plates, deposition of sediments in the deep ocean) or so fast and/or unpredictable they cannot be measured (e.g., landslides, formation of pseudotachylite in an earthquake). Much of the Earth (in fact, 99.9%) is inaccessible to geologist except by proxy records – the deepest drill hole (Kola Superdeep Borehole) is only 12 km deep, while the radius of the Earth is more than 6000 km. Because of the spatial and temporal scales over which geologic processes operate, and the difficulty in producing the pressure and temperature conditions observed even a few 10's of kilometers beneath the surface of the Earth, it is challenging to produce meaningful geological experiments. These challenges to the limits of knowledge in Earth Science are taught in all of our courses, as we particularly emphasize not just what we know, but how we know it. In ERS211H5, students engage in a personal research project proposal. As such, they are tasked with identifying a testable hypothesis, and devise means by which they could conduct their proposed research. Each project proposal is self-driven, and requires an extensive literature review. To begin, students are tasked with producing a detailed annotated bibliography in which they identify important discipline-specific knowledge they can utilize when constructing their arguments, and also identify discipline limits of knowledge that are necessary to justify the proposed research direction. Each proposal is also anonymously peer-reviewed, resulting in students critically thinking about specific discipline limits of knowledge as expressed by their peers so as to provide positive, and effective, feedback. These are combined with reviews from the instructor and TA – as such, students must manage comments from three individual points of view, and incorporate what will be, at times, conflicting opinions.

		In addition to exploring the limits of knowledge associated with Earth Science, students may explore their own limitations by applying critical thinking skills and practicing self-assessment. In the optional capstone JCB487Y5: AIRLab, on a weekly basis, all students are asked to individually prepare and submit a reflection (self-assessment) report to the course instructors, allowing these students to gain important metacognitive skills that go beyond our stated DLEs. The success of this approach is demonstrated in the peer-reviewed pedagogical article on AIRLab (Laflamme, M., Krull, U.J., deBraga, M. and Piunno, P.A., 2018. The Advanced Interdisciplinary Research Laboratory Course: Refinements, Reflections, and the Introduction of Earth Sciences. Journal of College Science Teaching, 48(1)). All of our 400-level courses will include the following components directly linked to DLE5: 1) an end-of-term paper that helps summarize knowledge acquired throughout the semester and identifies a discipline-specific limit of knowledge and 2) an annotated bibliography of primary literature that highlights the importance of each paper and requires students to reflect on the utility of the reference with regards to their research paper, and identify discipline-level limits of knowledge in order to form a research hypothesis.
6. Autonomy and Professional Capacity a. manage their own learning both within and outside the discipline, selecting an appropriate program of study b. uphold the ethical values of the University, including freedom of expression and enquiry and its principles of academic integrity, equity and inclusion c. exercise initiative, personal responsibility and accountability in personal and group contexts and decision-	Develop a sufficiently broad and rigorous scientific background to allow for a career or advanced study in geoscience	Certification by the Association of Professional Geologists of Ontario (APGO) is required in order to qualify as a professional geoscientist, and to practice or consult in Ontario. In order to become APGO-certified, students must meet specific knowledge requirements (see https://www.apgo.net/mpower/ktoolkit/public-requirements.action), then complete several years as a Geologist-in-Training. APGO-certification is required for all senior positions in Earth Sciences in Ontario. Also, each province has similar certification requirements; As such, APGO certification allows our students to practice their discipline all across Canada. The proposed changes to our curriculum will result in an APGO-compliant program. The strict guidelines set out by the APGO explains the specific course requirements (for example, the high volume of 100-level courses) outlined herein, and represents the first step for our students to gain employment in Earth Sciences. Students who successfully complete courses in one of the pathways will be able, upon graduation, to apply for the Geologist-in-Training status that will lead to the AGPO's Professional Geoscientist designation.

making in complex contexts d. acquire an appreciation of how their areas of study relate to their personal and professional development		Our program provides opportunities for student professional development. Most notably, our numerous active-learning experiential field courses (ERS225, ERS325, and the optional capstone ERS425) require students to develop confidence in collecting and interpreting data while in the field. For instance, when collecting geological data, students are trained to avoid geological interpretations until multiple independent lines of inquiry are applied. Once back from the field, students are required to interpret their findings through the application of petrographic studies, mapping, and facies analyses all learned as part of the foundational courses offered at UTM. These skills are highly marketable and necessary for a professional career. All of our 400-level courses will include the following components directly linked to DLE6: 1) an end-of-term paper based on a topic chosen by, and researched by, the student 2) an annotated bibliography of primary literature that highlights the importance of each paper and requires students to reflect on the utility of the reference with regards to their research paper, and identify personal and discipline-level limits of knowledge as it pertains to their research topic, 3) a peer-to-peer review exercise to provide critical feedback, and to allow students to reflect on their own writing practices, and 4) a public presentation where students showcase their personal research conducted over the semester. In our thesis courses (e.g. ERS470Y5, ERS471H5, ERS472H5) or ROP courses (ERS299Y5, ERS399Y5, ERS499Y5), many of our students are involved in the generation and presentation of original research (and follow the 400-level course requirements as listed above).

Appendix B: Current Calendar Copy

UNIVERSITY OF TORONTO
MISSISSAUGA

Earth Science (HBSc)

Professors

J. Halfar, Diplom, Ph.D., Habilitation
M. Laflamme, Ph.D., B.Sc.(Agr.)
L.M. Schoenbohm, B.A., Ph.D.
D.J. Schulze, B.A., M.Sc., Ph.D.

Chair

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Academic Counsellor/Program Administrator

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Earth Science is concerned with the origin, evolution and structure of Earth (and other planets), through the analysis of physical, chemical and biological processes.

In the last 40 years the field has been revolutionized by the discovery that the Earth's surface is a mosaic of plates that is continually moving, growing at mid-ocean ridges, and being consumed beneath mountain ranges. Modern global data sets provided by satellites continue to improve our understanding of these processes and of their environmental impact. Although exploration for natural resources continues to be the traditional vocation of geoscientists in the community, they are now playing a vital role responding to increased public and scientific awareness of environmental problems and issues.

Despite increasing sophistication in computer, satellite and analytical techniques, field observation remains a cornerstone of Earth Science. A career in Earth Science therefore can lead not only to laboratory or office-based opportunities, but also offers

scope to work in many parts of the world, under a range of field conditions. Oil and mining companies engaged in exploration and development, and those involved with environmental hazards, such as waste disposal, are all major employers of Earth Scientists. Provincial and Federal Geological Surveys also employ Earth Scientists and offer summer field assistantships. Other employment opportunities are in consulting, universities, and museums.

U of T Mississauga offers Specialist, Major and Minor programs in Earth Sciences. We also offer a Specialist program in Environmental Geosciences (HBSc), which meets the academic requirements for certification as a Professional Geologist in Ontario. These programs have four main aims: (1) to teach the fundamental processes involved in the global Earth system, with emphasis on the interactions between the solid Earth and its oceans, atmosphere and biosphere; (2) to understand the principal aspects of a sustainable and sufficient supply of natural resources; (3) to study the cause and mitigation of hazards such as earthquakes, volcanic eruptions and groundwater contamination, and (4) to learn how to minimize and adjust to global and environmental change. This approach, by focusing on a more global environmental perspective, should appeal to students who have a general interest in geological processes and their fundamental effects on the environment.

Students may combine Earth Science courses with those from other fields. A specialist in Geology is also available for students interested in pursuing careers in the resource industries or graduate studies in Geology. Many of our courses will be useful to students specializing in other fields such as Commerce, Geography, History and Biology.

Students should also review the Degree Requirements section prior to selecting courses

For courses in this area see:

ERS	Earth Science

Specialist Program ERSPE1465
Earth Science (Science)

11.0 credits are required, including at least 4.0 at the 300/400 level, of which 1.0 must be at the 400 level.

Limited Enrolment --Enrolment in this program is based on completion of 4.0 credits including (ERS101H5, ERS111H5) or ENV100Y5 (minimum grade of 60%).

First Year	(ERS101H5, ERS111H5) / ENV100Y5; (CHM110H5,120H5); MAT134Y5/ 135Y5/ 137Y5; (PHY136H5,137H5)/ (PHY146H5,147H5)
Second Year	ERS201H5, 202H5, 203H5, 211H5; 1.0 credit from ERS225H5/GGR214H5/ 217H5/ 227H5/ 272H5/ 276H5/ 278H5

Third Year	ERS325H5; 2.0 credits from ERS301H5/ 302H5/ 303H5/ 311H5/ 312H5/ 315H5/ JGE378H5; 0.5 credit from ERS381H5/ GGR315H5/ 316H5/ 321H5/ 337H5/ 379H5/ 384H5
Fourth Year	1.0 credit from ERS401H5/ 402H5/ 411H5/ 412H5/ 425H5/ 470Y5/ (471H5, 472H5) / JEG400Y5/ GGR407H5/ 463H5/ 464H5/ 484H5/ JCB487Y5/ ERI398H5/ CPS400Y5

GGR272H5 is a prerequisite for GGR278H5

Appendix C: Proposed Calendar Copy

UNIVERSITY OF TORONTO
MISSISSAUGA

Earth Science (HBSc)

Professors

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J. Halfar, Diplom, Ph.D., Habilitation
M. Laflamme, Ph.D.
S. K. Y. Liu, B.Sc., M.Sc., Ph.D.
L.M. Schoenbohm, B.A., Ph.D.

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Earth Science is concerned with the origin, evolution and structure of Earth (and other planets), through the analysis of physical, chemical and biological processes.

In the last 60 years the field has been revolutionized by the discovery that the Earth's

surface is a mosaic of plates that is continually moving, growing at mid-ocean ridges, and being consumed beneath mountain ranges. Modern global data sets provided by satellites continue to improve our understanding of these processes and of their environmental impact. Although exploration for natural resources continues to be the traditional vocation of geoscientists in the community, they are now playing a vital role responding to increased public and scientific awareness of environmental problems and issues.

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U of T Mississauga offers Specialist, Major and Minor programs in Earth Sciences. The Specialist program meets the academic requirements for certification as a Professional Geologist in Ontario. These programs have four main aims: (1) to teach the fundamental processes involved in the global Earth system, with emphasis on the interactions between the solid Earth and its oceans, atmosphere and biosphere; (2) to understand the principal aspects of a sustainable and sufficient supply of natural resources; (3) to study the cause and mitigation of hazards such as earthquakes, volcanic eruptions and groundwater contamination, and (4) to learn how to minimize and adjust to global and environmental change. This approach, by focusing on a more global environmental perspective, should appeal to students who have a general interest in geological processes and their fundamental effects on the environment.

Students may combine Earth Science courses with those from other fields. Many of our courses will be useful to students specializing in other fields such as Commerce, Geography, History, and Biology.

Students should also review the Degree Requirements section prior to selecting courses

For courses in this area see:

ERS	Earth Science

Specialist Program ERSPE1465
Earth Science (Science)

14.0 credits are required, including at least 5.0 at the 300/400-level, of which 1.0 must be at the 400 level.

Limited Enrolment --Enrolment in this program is based on completion of 4.0 credits including (ERS101H5 and ERS111H5), or ENV100Y5 (minimum grade of 60%).

First Year	(ERS101H5, ERS111H5) / ENV100Y5; (CHM110H5, CHM120H5); (MAT135H5, MAT136H5); (PHY136H5, PHY137H5) / (PHY146H5, PHY147H5); (BIO152H5, BIO153H5)
Second Year	ERS201H5, ERS202H5, ERS203H5, ERS211H5, ERS225H5; STA220H5
Third and Fourth Year	ERS301H5, ERS303H5, ERS311H5, ERS315H5, ERS325H5; 2.5 credits from (any ERS course at the 300-level or 400-level / GGR201H5 / GGR217H5 / JGE378H5); 1.0 credit from ERS at the 400 level or JCB487Y5

Notes:

1. No more than 1.0 credits from ERS399Y5/ERS499Y5/ERS470Y5/ERS471H5/ERS472H5 or JCB487Y5 can be counted toward the Earth Science specialist program.
2. While students may select any ERS courses for their 2.5 credits at the 300-level or higher, students may choose to take courses from one of the following two pathways for future certification by the Association of Professional Geologists of Ontario in their Geology and Environmental Geoscience oriented streams:

Resources, Hazards & Tectonics Pathway: ERS302H5, ERS304H5, ERS402H5, ERS403H5, ERS404H5, ERS425H5, JGE378H5, and 0.5 credits from ERS399Y5/ERS470Y5/ERS471H5/ERS472H5 or JCB487Y5.

Earth, Climate & Life Pathway: ERS304H5, ERS312H5, ERS411H5, ERS412H5, ERS425H5, GGR201H5, GGR217H5, and 0.5 credits from ERS399Y5/ERS470Y5/ERS471H5/ERS472H5 or JCB487Y5.