From “Gunter’s Chains” to Satellite Imaging:

A History of Science and the Ministry of Natural Resources and Forestry, 1967-2017

The last fifty years have seen significant scientific and technological advances in the field of natural resource management. The Ontario Ministry of Natural Resources and Forestry (MNRF), tasked with protecting and sustainably managing the province's diverse natural resources,[1] has taken many important strides over the decades to keep pace with the ever-changing scientific and technological landscape. The high profile of science within the Ministry is reflected in its organizational structure. Moreover, the many scientific and technological advances it has made, such as those in forestry, wildlife management and surveying, demonstrate that the MNRF has long been committed to promoting the use of scientific methods in the pursuit of protecting and managing Ontario's natural resources.

Before the 20th century, amateur "naturalists" dominated the realm of science, and this was certainly the case during the early history of Ontario, which was known as Upper Canada at the time.[2] The early predecessor departments of the MNRF, such as the Department of Crown Lands (established in 1827) and the Surveys Department (established in 1794) often employed very little in the way of science and made little use of scientific expertise on matters relating to their work. In the field of land surveying, for example, surveys performed prior to the 20th century were often fraught with error, due to the surveyors' primitive techniques, errors in their judgement, or other factors relating to their lack of technical training within the surveying field at the time.[3] In fact, from the founding of Upper Canada in 1791 until 1849, its surveyors were not required to have any prior qualifications or experience. For example, the first Surveyor-General

[1] "Published plans and annual reports 2015-2016: Ministry of Natural Resources and Forestry." Government of Ontario. April 10, 2017. Accessed April 16, 2017. https://www.ontario.ca/page/published-plans-and-annual-reports-2015-2016-ministry-natural-resources-and-forestry.
[2] Suzanne E. Zeller, *Inventing Canada: Early Victorian Science and the Idea of a Transcontinental Nation (Carleton Library Series)*. McGill-Queens University Press, 2009. 14.
[3] Richard S. Lambert and Paul Pross, *Renewing Nature's Wealth: A Centennial History of the Public Management of Lands, Forests, and Wildlife in Ontario, 1763-1967* (Toronto: Ontario Department of Lands and Forests, 1967), 66.

of Upper Canada, David William Smith, who held the position from 1794 to 1804, had no background in surveying.[4] By the 1830s the Surveys Department, which would be folded into the Crown Lands Department in 1837, had fallen into "the habit of employing incompetent and unqualified persons as surveyors, with the result that errors in surveys multiplied, purchasers were given overlapping titles and descriptions of their land, and fees were illegally charged to remedy the mistakes."[5] However, that changed in 1849 when legislation was passed that required new surveyors both to complete a three-year apprenticeship and pass examinations in fields such as geometry, trigonometry, astronomy, map-drawing, and mensuration (i.e. the part of geometry concerned with ascertaining lengths, areas, and volumes[6]). In 1860 the Association of Provincial Land Surveyors was established, and it organized surveyors into a professional body that helped standardize their qualifications.[7]

Various technologies have long been important to mapping and surveying work, all the way from the earliest days of surveying in Ontario to the present. The primary instruments used by surveyors during the early to mid-19th century were the compass and the survey chain. The latter was commonly known as a "Gunter's Chain" and named after English inventor Edmund Gunter, and it worked as a primitive measuring tape. Both devices were sometimes defective, however, as compass readings could be rendered inaccurate by magnetic deviations caused by bodies of mineral ore, and the Gunter's chain could also become tangled and worn out over time. As the 19th century progressed, more surveyors began using a more accurate "transit theodolite",

[4] Lambert and Pross, 49.
[5] Lambert and Pross, 54.
[6] *Oxford English Dictionary*, "Mensuration."
[7] Lambert and Pross, 67.

a device that uses astronomical observations to determine the position and direction of survey lines.[8]

From the beginning of the 20th century onward, the realm of surveying also began to experience many scientific advances, as the number of technologies at the disposal of Ontario's surveyors began to grow and allowed them to improve further upon their work. In 1900 the Gunter's chain gave way to the steel tape measure, a more accurate means of assessing lengths and distances, while theodolites continued to improve in telescopic strength and accuracy. The Ontario Department of Lands and Forests, which emerged from the Department of Crown Lands in 1905, began experimenting with aerial mapping and photography by performing the first aerial surveys of northeastern Ontario in 1920.[9] The advent of radio and motorized vehicles also allowed surveyors to cover greater areas in shorter amounts of time and increased the accuracy of their work.[10]

The science of forestry in Ontario traced a similar path of growth and advancement from the early days of Upper Canada until the late 19th century. Prior to the mid-1800s, little was done to apply science in managing the forests of Upper Canada. The Indigenous Anishinaabe peoples in northwestern Ontario and elsewhere were noted to have engaged in an early form of forest management when they deliberately and periodically burned forests and the landscape to facilitate the growth of blueberries and browse for ungulates, and to manage and lessen the fuel load for natural forest fires.[11] On the other hand, the Crown Lands Department devoted little effort towards scientifically managing Upper Canada's forest resources, as they were generally

[8] Lambert and Pross, 71.
[9] Lambert and Pross, 235-237.
[10] Lambert and Pross, 78.
[11] Davidson-Hunt, Environments, Peter A. Baskerville, *Sites of Power: A Concise History of Ontario* (Oxford University Press, 2005), 225.

seen as being "inexhaustible."[12] Early European settlers might have perceived North American forests as "dark, evil and menacing" at worst and merely an obstacle to agricultural development and settlement at best.[13] In the decades after Confederation, however, attitudes in the Crown Lands office began to change and officials began to realize the importance of conservation and gaining a greater understanding of forest management.

By the late 1800s, it was clear to many contemporary observers that the forests of Ontario were facing serious issues. In his 1865 *Annual Report*, Crown Lands Commissioner Alexander Campbell made recommendations to address them, including calling for "segregated land-use"[14] and declaring the need for "the adoption of Scandinavian practices of scientific forest management," which would mean the cropping of timber on a sustained yield basis.[15] A few decades later, the American Forestry Congress met for the first time in Montreal and Cincinnati to discuss the growing concerns over the way forests were managed in North America and on how best to prevent and combat forest fires.[16] It was at the Congress that forestry enthusiasts put together a series of recommendations for improving stewardship of the woods, and for implementing new scientific silvicultural methods. The Congress agreed that trained forestry personnel would be needed to implement the recommendations, and that forestry should receive greater emphasis in agricultural schools and universities.[17]

The first half of the 20th century saw Ontario make significant headway in the field of forestry. In 1927, for instance, the Ontario government unveiled the Forest Act, which

[12] Lambert and Pross, 150.
[13] Armson, K. A. *Ontario Forests: An Historical Perspective*. Toronto: Fitzhenry & Whiteside, 2001. 131-132.
[14] Lambert and Pross, 157.
[15] Lambert and Pross, 178.
[16] Armson, K. A. *Ontario Forests: An Historical Perspective*. Toronto: Fitzhenry & Whiteside, 2001. 131-132.
[17] Lambert and Pross, 178-181.

established a Forestry Board that was tasked in part with performing research on forestry-related matters. The Forestry Branch of the Department of Lands and Forests (DLF) soon created a research unit, which began investigating whether spruce and pine – the two most important commercial species – were regenerating adequately after an area was logged or burned. The results were disappointing, and they included the revelation that "pine seedlings in the mixed-wood forest were killed by the competition of the lush growth of broad leaved species that quickly took over the area after logging of the pine."[18] To address this problem, the DLF began working on ways to improve the reproduction of pine post harvesting, trying measures such as controlled or prescribed burns (like the Anishinaabe before them) and spraying chemical solutions on underbrush to reduce the level of competition that the pine seedlings faced. Unfortunately the stock market crash of 1929 and ensuing global depression meant that many forestry research projects came to a halt due to a lack of funding.[19]

The next several decades brought about several watershed moments in the DLF's forest research. In 1941, for instance, the DLF was reorganized and a new research division was established to carry out forestry research. One of the primary aims of this reorganization was to create a detailed "forest resource inventory", or FRI. The FRI programme brought together a wide number of specialists who mapped out thousands of square kilometres of the province's forests, thereby greatly improving the ability of the DLF to manage them.[20] The Research Division also began to perform experiments in the use of aerial spraying of insecticides, resumed forest generation survey work that had been discontinued in the 1930s, and developed a new system of forest soil classification. In 1946, the Research Division also began studying methods

[18] Lambert and Pross, 503-505.
[19] Armson, K. A. *Ontario Forests: An Historical Perspective*. Toronto: Fitzhenry & Whiteside, 2001: 144.
[20] Lambert and Pross, 404-407

on how to breed and inoculate pine trees that would be resistant to white pine blister rust. In the same year, it established its main research facility at Maple in southern Ontario. In the 1950s and 1960s, the DLF continued building on the advancements made by these research projects, making particularly great strides in forestry. For example, it experimented with growing tree seedlings in tubes (to facilitate planting) and conducted a number of studies on various tree species, with many projects focusing on the different varieties of spruce in particular.[21]

The 1970s saw a rising number of important advancements and developments in forestry after the Ministry of Natural Resources was established in 1972, and this was reflected in both the MNR's scientific efforts and its structural reorganization. For example, the 1970s witnessed a growing demand for poplar trees because new industrial products – such as "waferboard" panelling and "oriented strand board" – had been developed; new technology and processes had also expanded its usefulness in making pulp and paper.[22] As a result, the Forest Research Branch of the new MNR developed a number of fast-growing hybrid poplar clones, some of which were highly suitable for pulping.[23] The program yielded hybrid poplars which exhibited a higher degree of frost and disease resistance, a faster growth rate, and superior fibre quality.[24] In 1977, the Division of Forests was replaced with the Forest Resources Group, which amalgamated the Forest Research and Forest Management branches and also established the Ontario Forest Research Centre (OFRC) headquartered in Maple, Ontario. The OFRC would "provide scientific and technical knowledge and information to improve the management of forest resources in Ontario"[25] and would be the precursor to groups such as the Ontario Tree Improvement and

[21] Lambert and Pross, 501-511.
[22] Armson, K. A. *Ontario Forests: An Historical Perspective*. Toronto: Fitzhenry & Whiteside, 2001: 164.
[23] *Minister of Natural Resources: Annual Report* (1973): 4.
[24] *Minister of Natural Resources: Annual Report* (1977): 4.
[25] *Minister of Natural Resources: Annual Report* (1978): 5.

Forest Biomass Institute (OTIFBI), Ontario Forest Research Institute (OFRI) and the Centre for Northern Forest Ecosystem Research (CNFER). The establishment of the Ontario Forest Research Centre in 1977 reflected the growing focus the Ministry would place on science in the years to come. The OFRC conducted research through many channels, using its own scientists, contracts with post-secondary institutions and the private sector, and through co-operative programs with the Canadian Forestry Service and various similar institutes.[26] As in the case of its development of fast-growing poplar clones developed in the early 70s, almost all of its research was conducted with the aim of assisting the forest industry by breeding trees with genetic characteristics that made trees stronger and quicker growing, as well as more disease-resistant, for harvesting.[27]

The next decade brought about more progress in the area of forest research. For example, in 1983 the Ontario Tree Improvement Forest Biomass Institute (OTIFBI), which rose out of the OFRC, concluded work on its "Forest Ecosystem Classification Technique", a system whereby foresters could consult a universal forest classification system. While previously foresters could refer to different trees and vegetation types with accuracy, they did not yet use a universal system to describe types of forest ecosystems. Foresters could now use a computer system to determine how a forest should be cut and regenerated. This new information was well received by the forest industry, which it was noted would be the main beneficiaries of such a system. [28] In the late 1980s, MNR staff began using GIS (Geographic Information Systems) in integrating

[26] *Minister of Natural Resources: Annual Report* (1980): 7.
[27] *Minister of Natural Resources: Annual Report* (1978): 5.
[28] *Minister of Natural Resources: Annual Report* (1983): 16.

Forest Resource Inventory data with existing topographical information collected by the surveys division and compiling it into an accessible computer database.[29]

Other major changes occurred in the research field within the MNR during the 1980s. The decade saw the Ministry create four new Technology Development Units (TDUs) in Thunder Bay, North Bay, Timmins, and Brockville. The establishment of TDUs, which were responsible for "adapting technology for the needs of field foresters in Ontario,"[30] reflected the MNR's desire to conduct applied research that aided the forest industry and the importance of technology in this field.[31] For example, the TDU in Brockville was tasked with developing a "Fast Growing Hardwoods" program, which focused on developing hybrid poplars.[32] TDU staff were charged with responsibility for building "computerized databases about forests, holding technical workshops for foresters, and producing publications to keep foresters up to date on available technology and new developments in forest technology."[33] And in 1986-87 the MNR established the Northern Forest Biology Centre at Lakehead University (in Thunder Bay), which later became the Centre for Northern Forest Ecosystem Research (CNFER). It would conduct research on questions related to forestry in the Boreal Forest Region, boreal animal life, and other related topics.[34] The next year, the OTIFBI was reorganized and renamed the Ontario Forest Research Institute (OFRI). Beginning in 1990 it was based in Sault Ste. Marie after several decades of the Institute and its predecessors having been headquartered in Maple.

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[29] *Minister of Natural Resources: Annual Report* (1988-89): 12.
[30] *Minister of Natural Resources: Annual Report* (1988-89): 12.
[31] *Minister of Natural Resources: Annual Report* (1986-87): 20.
[32] Armson, K. A. *Ontario Forests: An Historical Perspective*. Toronto: Fitzhenry & Whiteside, 2001: 172.
[33] *Minister of Natural Resources: Annual Report* (1988-89): 12.
[34] Government of Ontario. "Forest research." https://www.ontario.ca/page/forest-research

The MNR has also been deeply involved in wildlife research over the last fifty years. For example, during the early 1970s it developed a number of new technologies to track and monitor various animal species. Initially these efforts and advances were often directed towards the MNR's work in the traditional fields of trapping, fishing and wildlife management, but later these advances were aimed at realizing its other goals as well, including the elimination of rabies. In 1972 the MNR's Division of Fish and Wildlife began conducting aerial censuses of beaver colonies, testing new types of beaver traps, and developing a computer program to analyse beavers for "weight, age structure, family size and pelt quality by trapline or township, and physiographic units."[35] The purpose of these studies was to help the fur industry by analysing beaver habitats and behaviours using the latest contemporary technology.

In 1973, the Ministry's Fish and Wildlife Research Branch noted that several major research projects were nearing fruition, including the continued development of nascent animal tracking technology and a program of vaccinating wildlife against rabies using an oral vaccine. With regard to the former endeavour, the MNR noted at the time that "continued development of a radio-tracking system bore valuable fruit" but unfortunately "full utilization of this tool is hampered by lack of the automated receiving equipment available through modern technology."[36] With regard to the latter, the Ministry conducted extensive trial runs of the rabies vaccine bait throughout the 1970s. The Ministry reported that its rabies research program "continued to provide interesting observations" and, more importantly, had clearly "verified the efficacy of a large-scale baiting strategy."[37] In 1976, the rabies program and the development of radio-tracking technology converged when "valuable information on the movement of foxes and

[35] *Minister of Natural Resources: Annual Report* (1973): 8-9.
[36] *Minister of Natural Resources: Annual Report* (1974): 12.
[37] *Ministry of Natural Resources: Annual Report* (1979), 24.

coyotes was gained by radio-tracking, giving greater understanding of these animals and of how rabies may be spread by wandering individuals."[38] In 1979 the Rabies Advisory Committee was established with a wide variety of independent experts who were charged with advising "on the scientific steps necessary for developing a suitable vaccine against rabies and an effective system for vaccinating wild animal populations."[39]

By the 1980s, the MNR had made significant progress in its development of radio-tracking technology, both in the level of sophistication of the technology and the amount of new scientific data its personnel had collected with it. The early 1980s in particular brought many scientific breakthroughs in animal tracking and tagging. For instance, in 1981 MNR scientists completed a long-term study on black bears that was greatly assisted by radio-tracking technology; researchers had been able to track the movements of 125 bears from 1969 to 1981. This study vastly improved scientific knowledge surrounding black bears, and it was in turn used to help the MNR in its bear management efforts.[40] In the same year, Ministry scientists began to use radio-tracking technology to follow the movements of fish when they attached sonar devices to lake trout in Algonquin Park.[41] With improved microchips and other technologies, the MNR was also able to develop smaller and smaller tracking devices that could collect information on the whereabouts of animals and could also track data such as animal den temperatures.[42] Around the same time, the MNR established an electronics design laboratory[43] with the aim of further developing telemetry technologies (telemetry is "the process of recording and transmitting the

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[38] *Minister of Natural Resources: Annual Report* (1977): 17.
[39] "Public Appointments Secretariat," *Government of Ontario*, https://www.pas.gov.on.ca/scripts/en/BoardDetails.asp?boardID=1037 (accessed 12 July 2017).
[40] *Minister of Natural Resources: Annual Report* (1981): 40-41.
[41] *Minister of Natural Resources: Annual Report* (1981): 48-49.
[42] *Minister of Natural Resources: Annual Report* (1981): 49.
[43] *Minister of Natural Resources: Annual Report* (1982): 36.

readings of an instrument."[44]). In the summer of 1984, scientists with the aid of the MNR's avionics department put these new technologies to the test when they tagged and tracked over 200 polar bears in Ontario's Far North, gleaning valuable information on the number and movement of the local polar bears.[45] In 2002, scientists from the MNR in association with several universities and institutes combined the use of radio telemetry and GIS in tracking and studying the spawning habits of lake trout.[46]

On the rabies front, the ministry continued its research efforts to develop a vaccine baiting strategy during the 1980s. Meanwhile, rabies cases increased with over 1,800 people treated after exposure to rabies in Ontario in 1981 alone. Much of the early research focused on determining the best time of year for the vaccine program to be effective, as well as the most cost-effective density of vaccine baits to vaccinate the required portion of wildlife populations. In 1989, MNR initiated the first large scale air drop of rabies vaccine baits in eastern Ontario.

By the early 1990s, after years of dedication and intensive research, the MNR's campaign against rabies began to show some serious progress. In 1991-1992, the Ministry allocated $2.1 million for rabies research and control, with a particular emphasis on foxes and skunks found in the central, southwestern, and eastern portions of the province.[47] The following year, Ontario lost its ranking among North American jurisdictions for having the highest number of rabies outbreaks, a title it had held for 25 years. Over the decades, the MNR made tremendous progress in its rabies vaccination program, which dropped thousands of vaccine-infused baits from the air, and by the mid-90's rabies in eastern Ontario had been almost entirely eliminated. The MNR's

[44] Oxford English Dictionary, "Telemetry."
[45] *Minister of Natural Resources: Annual Report* (1985): 42-44.
[46] Flavelle, Ridgway, Middel, Mckinley. "Integration of acoustic telemetry and GIS to identify potential spawning areas for lake trout (Salvelinus namaycush)." *Hydrobiologia* 483: 137–146, 2002.
[47] Ibid., 19.

success in this area did not go unnoticed, and in 1995 it was contracted by officials in Texas to implement its aerial baiting program to help control an outbreak among coyotes, dropping 850,000 baits over a 3,000 square kilometre area south of San Antonio.[48] After leading the development of new techniques and a new breakthrough vaccine in the mid-2000s which was able to successfully vaccinate all common rabies-carrying species in Ontario (fox, skunks, raccoons)[49] , Ontario recorded no cases of raccoon strain rabies in Ontario after 2005, and no cases of fox strain rabies after 2012, an impressive achievement and success story.[50]

After an absence of ten years, however, new cases of raccoon rabies were discovered in the Hamilton area in December 2015.[51] In response, the Ministry distributed 2.7 million oral rabies vaccine baits in 2016 and early 2017. As of November 2017, over 375 cases of raccoon strain rabies have been confirmed in southern Ontario since the December 2015 outbreak. The ministry continues to maintain its vaccine bait distribution program, and enhanced surveillance efforts suggest that the outbreak has been contained within 50 kilometres of the initial cases[52].

With the advent of satellite imaging and advancements in aerial photography in the latter half of the 20th century, the MNR has also gained important tools for creating maps and surveys. It established the Ontario Centre for Remote Sensing (OCRS) in 1973 under its Surveys and Mapping Branch. The OCRS was "created to provide special-mission aerial photography and interpretation of air-borne and space-borne imagery to the Provincial Government, to co-ordinate remote sensing activities within the Province, and to offer a source of remote sensing

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[48] *Minister of Natural Resources: Annual Report* (1992-95): 3.
[49] "Results-based Plan," *Ministry of Natural Resources* (2007-2008): 27.
[50] "Results-based Plan," *Ministry of Natural Resources* (2008-2009): 35.
[51] Trewby H, Nadin-Davis SA, Real LA, Biek R. "Processes Underlying Rabies Virus Incursions across US-Canada Border as Revealed by Whole-Genome Phylogeography." *Emerging Infectious Diseases*, Volume 23, No. 9, September 2017. Available from www.cdc.gov/eid/article/23/9/17-0325_article.
[52] Government of Ontario. "Rabies in Wildlife." https://www.ontario.ca/page/rabies-wildlife

information, including a library of satellite imagery, to the general public."[53] Satellite mapping was noted to be about "10 times faster and one-tenth as costly" as traditional ground-based methods of field surveying.[54] In 1977-78, the OCRS successfully implemented for the first time in Canada an aerial thermographic technique that allowed it to detect building heat loss in Lindsay, Peterborough, Stratford, Guelph, Brockville, Kingston, St. Catharines, Windsor, Kapuskasing and Cochrane. The findings from this project were presented to residential home owners in an effort to assist them with their energy conservation efforts.[55] Also at this time, the Centre acquired the capability for digital image analysis, which allowed for "the extraction of much finer detail from satellite data and greatly broadened the scope of applicability of space borne remote sensing in Ontario."[56]

In the early 1980s, the OCRS began trying to generate precise data regarding how much land there was in Ontario, and how much of it was both cleared and covered by water, wetlands and forests.[57] While the MNR had rough information regarding these questions, its officials could not provide exact answers to questions about much of Ontario's topography. Thereafter, the OCRS and the MNR worked specifically on mapping Ontario's peatlands, and by 1984-85 they had mapped over 200,000 square kilometres of the province and produced over 800 maps. Other provinces in Canada recognized the leading role Ontario was taking in applying this new technology, and during this period the governments of both Quebec and Newfoundland asked the MNR to implement peatland mapping pilot projects in their provinces.[58] The OCRS also began

[53] *Minister of Natural Resources: Annual Report* (1974): 26.
[54] *Minister of Natural Resources: Annual Report* (1985): 24.
[55] *Minister of Natural Resources: Annual Report* (1978): 22.
[56] *Minister of Natural Resources: Annual Report* (1978): 22.
[57] *Minister of Natural Resources: Annual Report* (1981): 29.
[58] *Minister of Natural Resources: Annual Report* (1985): 24.

taking an inventory of land use and land cover types by using computers to analyze data about the earth's surface transmitted by orbiting "LANDSAT" satellites. The satellites could survey areas as tiny as one acre with an astounding degree of accuracy.[59] The MNR also continued to perform aerial thermographic surveys of residential areas to assist in energy conservation efforts, and also "monitor heat generated by leaks from sanitary landfill sites; as a means of checking for sources of water pollution; and to pinpoint areas which are prone to frost formation, as an aid to reforestation."[60]

The 1970s and 1980s also brought about technological changes with the proliferation of computer technology. In 1977 the MNR noted that it was beginning to use computer programs to help create more accurate maps and surveys in its various branches and departmental Surveying and Mapping sections.[61] Computer technology would take on an ever expanding role in the MNR's administrative and research activities, and by the mid-1980s MNR personnel were making ever greater use of computer database systems to assist in their research.[62]

Advances in computer and satellite technology also greatly accelerated developments in Geographic Information Systems (GIS) just as public demand for this type of data was growing by leaps and bounds. GIS is a "system which consolidates information about land and its natural and man-made features into an easy-to-use computerized form" and "stores, correlates and analyses information about everything from geographical features and soil conditions to storm sewers and hydro lines."[63] In adopting this new technology, the MNR combined the information

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[59] *Minister of Natural Resources: Annual Report* (1981): 29.
[60] *Minister of Natural Resources: Annual Report* (1981): 29.
[61] *Minister of Natural Resources: Annual Report* (1977): 23.
[62] *Minister of Natural Resources: Annual Report* (1981): 25. And *Minister of Natural Resources: Annual Report* (1985): 6.
[63] *Minister of Natural Resources: Annual Report* (1988-1989): 31.

generated by the OCRS and its own traditional surveys, which allowed the ministry to produce maps with an unprecedented degree of accuracy. To aid these developments further, the MNR's Geodetic Services section began work on developing a Global Positioning System (GPS) to ensure greater consistency in its map-making efforts. The technology was also found to be a useful tool in traditional areas such as cartography, allowing the MNR to correct errors that were decades or even centuries old in maps that had been drawn with the aid of only a compass and a "steady eye."[64]

In July 1998, the Ontario government created Land Information Ontario (LIO), which the MNR would oversee. The LIO was tasked with collaborating with other ministries and levels of government to manage geographic data and land information projects and develop frameworks and policies relating to land information management in Ontario.[65] Today, LIO works to encourage and support the sharing of geographic data about Ontario and has a data warehouse with more than 300 data sets that include geographic information on Ontario's road network, trails, wetlands, lakes, rivers and streams, parks and protected areas, soil types, heritage sites, airports, official names and municipal boundaries.[66]

Over the last several decades the Ministry also made important strides in working towards using science and technology to help tackle climate change. The Ministry has done this by adopting policies and procedures with the goal of reducing greenhouse gas emissions and by developing plans and frameworks to adapt to the impacts of climate change.[67] The MNR began this process in the late 1980s, when it started examining the effects that climate change was

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[64] *Minister of Natural Resources: Annual Report* (1989-1990): 31.
[65] *Minister of Natural Resources: Business Plan* (1999-2000): 5.
[66] *Land Information Office, Ministry of Natural Resources and Forestry.*
[67] Government of Ontario. *A Practitioners Guide to Climate Change Adaptation in Ontario's Ecosystems*. Sudbury, Ontario: Ontario Centre for Climate Impacts and Adaptation Resources, (2011): 8.

having and would have on forests, fisheries, and Ontario's fresh water supplies.[68] The MNR continued this work during the 1990s, and in 1999 the MNR hosted a conference on "Preparing for Climate Change."[69] Moreover, the new millennium brought about a surge of climate change related policy developments by the MNR. In 2006-7, for example, it began investigating the "development of clean, renewable energy sources by investing in an alternative energy project to convert forest waste to a bio-liquid that can be used as a fuel for heat and electricity."[70] At the same time, in an effort to reduce greenhouse gas emissions the Ontario government released *Go Green: Ontario's Action Plan on Climate Change* and appointed an Expert Panel on Climate Change Adaptation to evaluate government programs and offer recommendations on paths for going forward.[71] Then in 2011, the MNR began implementing "Climate Ready: Ontario's Adaptation Strategy and Action Plan 2011-2014". It entailed the Ministry working with its partners to plant 50 million trees by 2020 with the goal of sequestering 6.6 million tonnes of carbon dioxide from the atmosphere.[72] Additionally, as part of the MNR's broader efforts to research and tackle climate change, it established the "Ontario Centre for Climate Impacts and Adaptation Resources" (OCCIAR), an organization that "communicates the latest research on climate change impacts and adaptation; liaises with partners across Canada to encourage adaptation to climate change and aids in the development of tools to assist with municipal adaptation."[73]

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[68] *Minister of Natural Resources: Annual Report* (1988-89): 13, 19, 28.
[69] *Minister of Natural Resources: Business Plan* (1999-2000): 5.
[70] "Results-based Plan," *Ministry of Natural Resources* (2006-2007): 21.
[71] Government of Ontario. *A Practitioners Guide to Climate Change Adaptation in Ontario's Ecosystems*. Sudbury, Ontario: Ontario Centre for Climate Impacts and Adaptation Resources, (2011): 8.
[72] "Results-based Plan," *Ministry of Natural Resources* (2014-2015): 12.
[73] Government of Ontario. "Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR)". http://www.climateontario.ca. Website contains a full listing of research and publications by the OCCIAR.

The Ontario Ministry of Natural Resources and Forestry (renamed in 2014) has made tremendous strides in the development of scientific research and technology since 1791, and especially so in the last 50 years. After the Ontario Ministry of Natural Resources (MNR) was formed in 1972, science played an ever increasing role in its activities. The importance of incorporating science into resource management since 1972 has been reflected in its work to control the spread of fish- and wildlife-borne diseases, its international stature in the field of forestry, and in its research into the effects of climate change. From the establishment of the MNR in 1972 to the present, in accordance with the importance it has placed on science and technology, the MNR has made many important strides in forestry, wildlife management, surveying and in its efforts to combat climate change. The history of science and resource management in Ontario has been a story of steady advancement and development since the early days of Upper Canada. While progress was slow in the early years, Ontario has made a great deal of headway over the last half century in terms of incorporating science into managing the province's bounty of natural resources.