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Communicating Groundwater Expertise Using
the Internet

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Management Perspective

The Internet is a global assemblage of computer networks that allows users to navigate a vast array of information resources. More than 30 million persons world-wide have access to the Internet. This paper outlines the efforts of the Groundwater Remediation Project (GWRP) of the National Water Research Institute of Environment Canada in developing a suite of Internet services targeted toward increasing the recognition of the research contributions of the Project and assisting in the delivery of these results to the public and private sectors. Considerable progress has been achieved during the first 40 weeks of operation of an Internet server that provides World-Wide Web, anonymous File Transfer Protocol, and automatic electronic mailing list management services. To date, approximately 6000 users have accessed the World-Wide Web component of the server where these entries represent 39 of the 80 countries that currently have Internet access. The ancillary benefits of using the Internet as an element of the Project's business practice include accelerated delivery of the Project's research results to an enlarged audience and a tangible reduction in the overhead associated with the deployment of these results. The GWRP will remain proactive relative to the use of the Internet as a method of communicating groundwater expertise.

COMMUNICATING GROUNDWATER EXPERTISE USING THE INTERNET

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Abstract

The emergence of the Internet as a prototype of the so-called "Information Superhighway" offers unique opportunities for the communication of scientific expertise. The Groundwater Remediation Project of the National Water Research Institute of Environment Canada is committed to using the Internet as a method of communicating the Project's research results, presenting Canadian groundwater issues, cataloguing on-line resources for groundwater studies, and disseminating groundwater-related educational materials. This paper describes the efforts and philosophy of the Project in establishing a range of Internet services, and in estimating the effectiveness of these services through access statistics collected for our World-Wide Web server, which is located at <http://gwrp.cciw.ca> on the Internet.

Introduction

The Internet is essentially an outgrowth of the Advanced Research Project Agency Network, a defense-oriented computer network developed in the United States during the 1960's and 1970's. Today, the Internet may be defined as a world-wide assemblage of computer networks that communicate using a common language, the Transmission Control Protocol/Internet Protocol (TCP/IP). Similarly, while the capabilities of the Internet have been exploited by a small and exclusive user group for many years, it is only very recently that the Internet has emerged as a feature of popular culture. Statistics indicate that the Internet now hosts well over 30 million users distributed among more than 80 countries and 3 million networked computers (American Geophysical Union, 1994).

This paper outlines the philosophy of the Groundwater Remediation Project (GWRP) of the National Water Research Institute of Environment Canada in accepting the Internet as an element of the Project's business practice, describes the services currently supported by the GWRP Internet server, and examines the response of Internet users to these services. This account of the entry of the GWRP into the realm of Internet information providers may be of interest to persons who are in search of on-line sources of groundwater expertise, colleagues who maintain allied on-line resources, and organizations contemplating the introduction of similar services. This paper does not describe the information content of the GWRP server or the software and hardware required to access these resources. The former is best appreciated first-hand by accessing the server through the Internet. Persons who require assistance regarding the latter should contact their computer services representative or Internet access provider.

Philosophy for the Provision of Internet Services

Over the past few years, it has become increasingly difficult to ignore the Internet. Much of this recent surge in popularity appears to be due to the evolution of the World-Wide Web (WWW), a technology that allows computer users to navigate the Internet in a user friendly and intuitive manner. The WWW is based on a client - server arrangement (Schatz and Hardin, 1994) where the client software (e.g., NCSA Mosaic, Netscape, or Lynx) handles user interaction, transmitting requests to the remote server and receiving and interpreting the ensuing response, and the server software (e.g., an HTTPD driver running on a UNIX workstation) handles information interaction, receiving and interpreting requests from the client and transmitting the required response back to the client. The WWW is referred to as a system of global hypermedia (Schatz and Hardin, 1994) where the term "global" indicates that the information accessed via the WWW is indeed globally distributed and the term "hypermedia" indicates that this information assumes numerous forms; namely, text, images, and sound and video segments. A wide variety of client and server software are available at a nominal cost, or for free, for a range of computers and operating systems including numerous UNIX implementations, X and Microsoft Windows, and the Macintosh.

Recognizing the emerging importance of the Internet, the GWRP began to explore the ways in which the Project could use the Internet as an element of business practice. The first step in this process was an assessment of whether an

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Internet server maintained by the GWRP, and focusing on groundwater issues, would make a useful contribution to the groundwater community while achieving meaningful corporate objectives. A review of existing Internet resources related to groundwater was conducted during May and June 1994 and returned minimal results, with only a few servers representing groundwater issues to an appreciable extent. This research led to the conclusion that an Internet server would increase recognition of the research contributions of the GWRP world-wide, paralleling the growth of the Internet. A server would also reduce the overhead associated with the deployment of the Project's research contributions while accelerating the delivery of these results to an enlarged audience. For example; reports and software could be distributed via the Internet more rapidly and widely than through traditional media with reduced effort and cost. Finally, a server would assist in fulfilling the mandate of the GWRP to transfer technology and groundwater expertise to the public and private sectors. At this point it was also concluded that the operation of a server would require measurable time and effort, and that routine monitoring of the response of Internet users to the server would be critical to balancing the effort associated with maintaining the server relative to the benefits gained through the operation of the server.

The next step in this process was determining the extent to which an Internet server could be developed within the constraint of using in-house expertise, existing hardware, and public domain software. It was determined that adequate expertise in two areas was readily available. First, knowledge of issues such as server configuration could be obtained through the Research Support Branch of the National Water Research Institute. Second, the expertise required to assemble the information content of the server could be obtained through the staff of the GWRP. Further, it was determined that Internet access to several computers maintained by the GWRP was feasible, and that the software required for the development of an Internet server was available within the public domain.

Finally, it was suggested that four general themes would be represented using the proposed server. These include: 1) presentation of the research activities and results of the GWRP, 2) presentation of information related to Canadian groundwater issues, 3) presentation of groundwater expertise originating from the Internet, and 4) presentation of groundwater-related education materials that could be used within secondary or post-secondary curricula.

Description of the GWRP Internet Services

Having decided to proceed with the implementation of Internet services, the GWRP committed a Silicon Graphics Personal Iris workstation to function as an Internet server. Two other UNIX workstations and numerous IBM compatible personal computers provide a backup capacity in the event of hardware failure. This server has been assigned the domain name *gwrp.cciw.ca* and currently has the numerical address 192.75.68.65. To date, three distinct services have been implemented on this server. The following paragraphs briefly outline these services; details regarding these services are widely available (Pike et al., 1994 or any of numerous texts available through libraries and bookstores). Vast amounts of information regarding the Internet and the topical resources that are represented on the Internet are also available on-line. Many of the myriad of WWW servers and Usenet electronic news groups include hyperlinks to these resources so, once Internet access has been secured, exploration of the Internet becomes a cycle of discovering new resources and using these resources to further the exploration effort.

An Hypertext Transfer Protocol (HTTP) server is the key component of the integrated GWRP server. This server receives HTTP requests from WWW clients and responds to these requests by transmitting a variety of hypermedia. The intuitive nature of hypermedia make this medium the most convenient method of arranging the information resources presented on the server. Also, formatting these media using the Hypertext Mark-up Language (HTML) is sufficiently straight forward that routine maintenance of the server can be performed by GWRP staff.

Figure 1 shows a portion of a description of the research activities of the GWRP in the area of fractured media flow and transport. Here, NCSA Mosaic running under Microsoft Windows has been used to retrieve and display the hypertext document that forms the description of the Groundwater Geomechanics Study. This hypertext includes a number of embedded hyperlinks to other hypermedia. The image that accompanies the textual description of the study was retrieved by selecting a highlighted term from the description, a hyperlink, and the corresponding graphic was transmitted to Mosaic by the HTTP server and was mapped to LView Pro for display. Numerous hypermedia types including formatted text ("*html*" and "*txt*" files), images ("*gif*" and "*jpg*" files), postscript documents ("*ps*" files), audio segments ("*au*" and "*wav*" files), and video segments ("*mpg*" and "*mov*" files) can be hyperlinked such that they may be retrieved by the WWW client and mapped to the external application that is appropriate to the content of the media. These external applications are widely available on the Internet, again at a minimal cost or for free.

The address or Uniform Resource Locator (URL) for the GWRP Internet server is *http://gwrp.cciw.ca*. This is the address that must be transmitted by the client software to initiate communication with the server. Once the client has

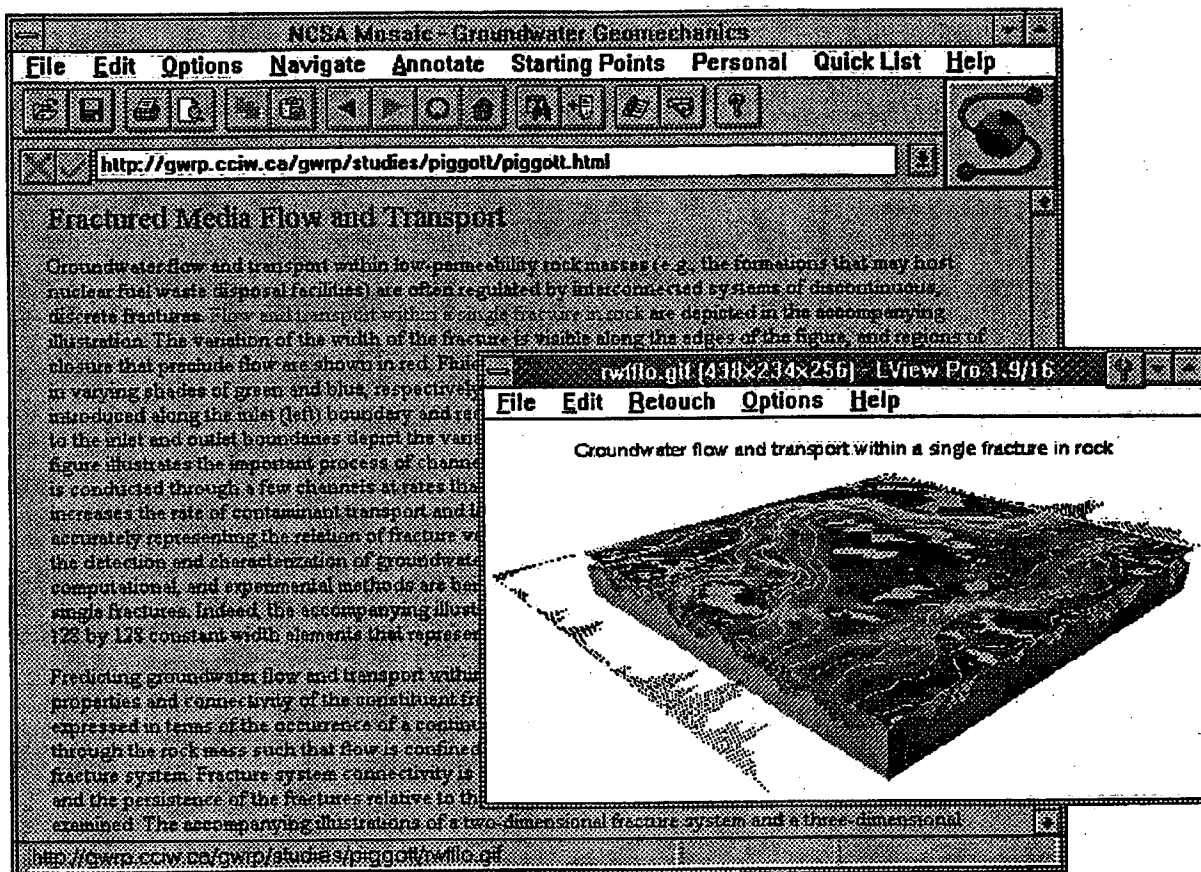


Fig. 1. Typical view of the GWRP WWW server. The textual portion of the document (PIGGOTT.HTML) was displayed from the HTML formatted source using NCSA Mosaic; the accompanying GIF formatted graphic (RWFFLO.GIF) was requested by selecting the highlighted hyperlink from within the text, and was mapped to LView Pro for display.

retrieved the welcome page from the server, the remainder of the hypertext document set can be accessed by following the embedded hyperlinks. Searching tools are integrated into the server such that one may select from a list of search terms, submit the selected term to the server, and receive a listing of all of the documents that relate to that term. This facilitates navigation through the contents of the server, making the content more accessible and therefore more useful. Other interactive facilities are available through the Common Gateway Interface (CGI) specification, which allows a client to transmit information to the server for remote processing. One such application is a groundwater modelling exercise that allows WWW users to remotely operate a simple FORTRAN coded groundwater model and apply the model to a sensitivity study of leachate migration from a landfill to an underlying aquifer.

The GWRP server also provides an anonymous File Transfer Protocol (FTP) capacity. Anonymous FTP allows client software to transfer ASCII text files or binary spreadsheet or word processor files to and from the server electronically, thereby reducing the cost and delay of sending the same files on diskette through courier or postal services. The anonymous FTP component of the server also allows clients to recover software products developed by the GWRP from a permanent archive; a function that is often performed using WWW clients such as NCSA Mosaic. The FTP server access log and a hypertext registration form are used to track the recovery of these products so that the contributing authors are advised of the distribution of their software. Numerous software products are available on the server, and a significant number of retrievals of these products have been recorded to date.

MAJORDOMO is an automated electronic mailing list management system and is the most recent addition to the Internet server. Under this system, a series of lists of electronic mail addresses are maintained such that messages sent to the list address are automatically distributed to all of the persons on the list via return e-mail. Subscription requests are sent to the robot mailing list manager and the addresses contained within the requests are automatically

added to the list of subscribers. The Groundwater Modelling Mailing List (GWM-L) was the first list installed under this system. Requests for subscription to this list are sent to majordomo@grp.cciw.ca and contain the message *subscribe gwm-l*. Items to be distributed across the GWM-L list are sent to gwm-l@grp.cciw.ca. At the time of writing there were approximately 290 subscribers to GWM-L. Requests for additional information regarding the GWM-L list should be sent to Andrew.Piggott@CCIW.Ca. Two other electronic mailing lists are currently under development. These are Canadian Hydrogeology (GWCAN-L) and a list for the use of Federal, Provincial, and Municipal government representatives in Canada who have an interest in groundwater issues (GWGOV-L). Inquires regarding GWCAN-L and GWGOV-L should be sent to Pat.Lapcevic@CCIW.Ca and Allan.Crowe@CCIW.Ca, respectively.

Measuring the Effectiveness of the GWRP Internet Services

It is premature to conclude that the GWRP server has achieved the objectives of increased corporate recognition and improved performance in the communication of research results and in technology transfer. It can be stated however that usage of the three services supported by the server has been consistently increasing since the introduction of the services. The most detailed evidence of the response of Internet users to the server is obtained by monitoring the access log maintained by the HTTP component of the server. This log records each HTTP request sent to the server, indicating the name of the client computer and the hypermedia requested by the client. This information is routinely processed to determine the total number of entries into the server and the number of unique entries into the server. An entry is recorded each time a computer submits an HTTP request to the server more than 8 hours after any previous request from that computer; the 8 hour interval is used to distinguish entries on different days or from workplace and home computers. A unique entry is recorded when a computer first submits an HTTP request to the server.

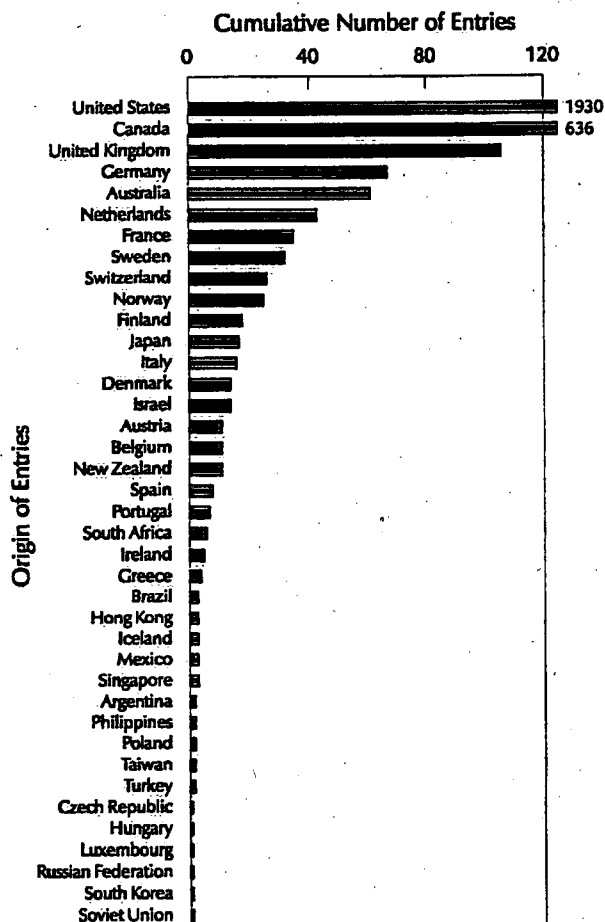


Fig. 2. Distribution by national origin of unique entries into the HTTP component of GWRP Internet server.

Figures 2 and 3 depict the results of the analysis of the access log for the period of June 27, 1994 to April 2, 1995; the first 40 weeks of announced operation of the HTTP component of the server. Figure 2 illustrates the distribution of unique entries according to national origin. Entries from the United States and Canada account for 82 percent of the total number of entries. It should be noted that the entries allocated to the United States include various sub-domain names such as "edu" and "com" which, in some cases, have been applied to computers that are not located within the United States. Thus, the results shown in Figure 2 may be skewed toward entries from the United States. A total of 39 countries are represented in Figure 2. This is taken to be a positive indication of the exposure of the HTTP component of the server to a broad, international constituency as this count represents one-half of the number of countries that currently have Internet access.

Entries into the server occur at a rate of several hundred per week where this count varies considerably from week to week. For example, a substantial reduction in entries was noted prior to and during the holiday season of 1994. This may be an indication of the extent of academic use of the server as this period corresponds to the end-of-semester exam schedule. Figure 3 shows the cumulative number of entries into the server as a function of time where the indicated holiday period occurs in the vicinity of week 25. The majority of entries were recorded during the latter half of the survey period. This is likely to be the result of an effort to promote the server by arranging for hyperlinks to the server from related servers; for example, from the WWW Virtual Library for Earth Sciences, the WWW Geographical Index, and from WWW servers maintained by the United

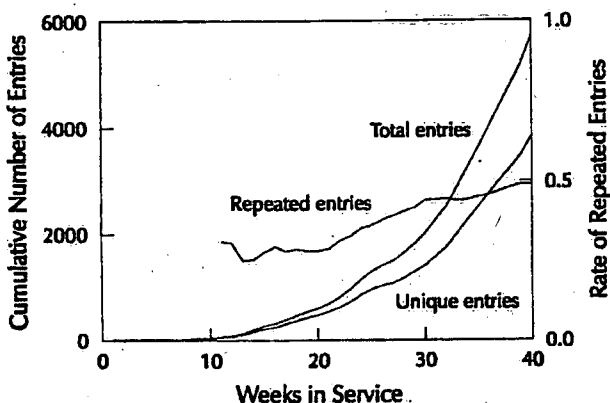


Fig. 3. Record of the cumulative number of entries into the HTTP component of GWRP Internet server.

States Geological Survey and Environmental Protection Agency. The GWRP server is also registered with several of the facilities that allow WWW users to search through topical Internet resources, Web-wide.

The growing difference between the total number of entries and the number of unique entries is an indication that the information resources that are presented on the server are sufficiently useful as to warrant repeated referral. The number of repeated entries into the server, relative to the number of unique entries, is shown as a function of time in Figure 2. There is an obvious trend for this metric to increase over the duration of the survey. Hopefully, this result indicates that the development of the server has been successfully directed, but it may also indicate that fewer entries are "accidental" in that they do not represent an interest in pursuing groundwater-related information.

Additional analyses of the HTTP server access log indicate that the majority of entries occur on weekdays during the hours of 9 am to 6 pm. This suggests that most entries correspond academic and corporate use of the Internet. The number of entries during the hours of 6 pm to midnight is greater than during the hours of midnight to 9 am. The GWRP server is situated in Burlington, Ontario in the Eastern Time Zone and the increased number of entries during the evening may indicate entries from sites in the Central, Mountain, and Pacific Time Zones of North America. The early morning entries may correspond to sites located in Europe since the period of midnight to 6 am in Burlington corresponds to 6 am to noon in Europe. Clearly, the peak demands on the server in responding to HTTP requests occurs during weekday, working hours and this outcome has ramifications relative to the ability of the server to function outside of the role of Internet server. Persons using the server for computationally intensive tasks have detected some reduction in the performance of the workstation during the peak demand period, but this influence is minimal and does not preclude the use of the computer for other tasks. This condition may change, however, as additional interactive facilities and larger media, particularly sound and video segments, are added to the server.

Examining the access log provides evidence of the response of Internet users to the HTTP server, but does not precisely define the audience that the server attracts. For example, the access log includes many entries from universities located in the United States (as indicated by the "edu" sub-domain name) but does not indicate whether these entries correspond to undergraduate or graduate students or to faculty members, each of which may require the content of the server to be differently presented. Thus, further work is required to define the audience of the server and the materials that are most useful to this audience. An informal survey of persons accessing the server was conducted in conjunction with the preparation of this paper. The responses that were received indicate both academic and corporate users with a consistent interest in groundwater and earth sciences information.

Future Directions

Change is a characteristic of the Internet and is an issue that must be addressed in the maintenance of the GWRP server. Failure to assume a proactive stance relative to changes within the Internet, and to continue to develop the server in terms of information resources and services, will be very likely to erode the ability of the server to achieve the indicated objectives. Ensuring that those persons who routinely contribute to the server allocate adequate time to navigating the Internet in search of new information resources and services should be sufficient to ensure that the server remains up to date relative to changes within the Internet. Securing feedback from persons accessing the server is the best method of defining the resources and services that require additional development. This is particularly true in situations where the information required by the users was either not found or was unavailable. Facilities for recording comments have been integrated into the server, but usage of these mechanisms has been very limited to date. Those comments that have been submitted are consistently favourable.

The increasing number of persons and organizations that have access to the Internet implies an expanding market for the expertise and services provided by the GWRP. Indeed, much of the recent growth in the use of the Internet is in disciplines such as the earth sciences where the required software tools have only recently become sufficiently accessible and user friendly as to encourage routine use. This trend has an ironic, negative impact in that the volume

of information passing over the Internet is also rapidly expanding (Waldrop, 1994). Ultimately, this trend may affect the function of the Internet services provided by the GWRP. Specifically, a delayed response to an HTTP or FTP request due to severe traffic on the Internet may lead a user to abort the request and ignore the target resource. Development of the Internet server will therefore proceed with the objective of guiding clients through the document set without intermediate reference to large textual or graphical elements. Increased capacity will undoubtedly be added to the Internet in the future, but it is not yet certain when this will occur and what the implications of this expansion will be in terms of the cost of access to the Internet.

Conclusions

The GWRP has assembled an array of Internet services that includes HTTP and FTP servers and an automated electronic mailing list manager. Combined, these services provide effective representation of the GWRP on the Internet and contribute useful groundwater-related information that can be accessed by the entire Internet community. The majority of this development effort was performed by Project staff, indicating that the implementation of Internet services is feasible for similarly provisioned organizations. While the GWRP regards this effort as being in its infancy, the server has already achieved an encouraging measure of appreciation from that portion of the groundwater community that has Internet access. Presumably this response will escalate as additional groundwater scientists and engineers gain Internet access. The statistics reported in this paper indicate that many persons and organizations are being introduced to the GWRP through the Internet, and this demonstrates progress toward the objective of achieving increased corporate recognition. Further, presentation of research results via the server accelerates the delivery of this information and has already led to several collaborative initiatives. Considerable savings in terms of effort and cost have already been achieved through the representation of the GWRP on the Internet. Finally, there is Project-wide reliance on Internet services such as e-mail and anonymous FTP to perform functions that would previously been carried out by telephone or facsimile or by postal or courier service. This has obvious implications in terms of administrative effort and operating expenses, and is particularly welcome since the savings that can be achieved in these areas can be diverted toward the research activities that ultimately contribute to the development of the server.

In summary, the GWRP regards use of the Internet as an important element of the Project's business practice. Even if the current popularity of the Internet diminishes in coming years, the gains that will be realized in the short term warrant the modest resources that have been allocated to the development of the Project's Internet services. All persons who have an interest in groundwater or earth sciences issues are invited to examine our WWW server, which is located at <http://gwrp.cciw.ca> on the Internet. Comments or questions regarding the Internet services provided by the GWRP should be directed to *Andrew.Piggott@CCIW.Ca*.

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