REPORT ON

JURISDICTIONAL SCAN AND GEOMATICS ANALYSIS

EV4919

ARCHIBALD ROBB CONSULTING

AND

AURORA GEOSCIENCES LTD.

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1. EXECUTIVE SUMMARY

The Government of the Northwest Territories (GNWT) Department of Industry, Tourism and Investment (ITI) contracted Archibald Robb Consulting (ARC) "to provide objective and comprehensive staking scenario cross jurisdictional research on the advantages and disadvantages of OMS scenario" Specifically, the objective of the study is to analyze the grid or no-grid methodologies to assist GNWT in deciding which of these two methodologies will be adopted by GNWT. ARC sub- contracted Aurora Geosciences Ltd. (AGL) for expertise in geomatics.

ARC undertook research on various jurisdictions with active mineral sectors to select a number to assess in more detail. Jurisdictions in Canada and internationally (Australia, South America, Africa)[1] were reviewed and a list of six was finalized and presented to ITI. ITI officials concurred with this selection. Three of these jurisdictions (British Columbia (BC), Ontario, and Nunavut) utilize a "grid" approach and three (Namibia, Tanzania, and Greenland) use a no-grid approach. The three jurisdictions using a grid are all Canadian and were chosen to reflect different approaches to conversion of legacy tenure and in the case of Nunavut proximity and similarity to the NWT. Selection of three non-grid jurisdictions was more difficult as majority of jurisdictions with On-Line Map-Staking (OMS) in place have utilized a grid approach.

A questionnaire was developed with the cooperation of ITI officials so that the six jurisdictions could be interviewed. The Mining Recorders Office (MRO) provided contacts for Canadian jurisdictions. The Canadian Trade Commission Officers in Tanzania and Namibia were approached to assist in reaching out to appropriate officials in those two countries. Two jurisdictions were very responsive (Greenland and British Columbia), two other Canadian jurisdictions needed to be elevated for senior management of ITI to request follow up and both jurisdiction in Africa eventually responded after two different approaches. Reason for lack of timely response is likely related to the time of year (particularly in Canada with people on summer vacation) and the impact of COVID, particularly in Africa – during the Namibia interview it was mentioned that June and July were not great in terms of COVID. The interviews were extremely informative. There were no responses from the various industry associations contacted.

Based on the interviews with the six jurisdictions, it is apparent that none undertook detailed analyses of the advantages and disadvantages of grid vs no-grid approaches to OMS. In some interviews, there seemed to be a lack of understanding of the choice between grid and no-grid approaches. This may have been based on the expertise of the individual(s) available for interview.

In British Columbia, the individual interviewed was not involved in early decision making but was not aware of any discussion on this. Ontario specifically mentioned that the technology selected worked better with a grid and one individual from Nunavut indicted that they did not recall any discussion around the possibility of not implementing a grid. Namibia noted the costs and complexity associated with implementing a grid solution by other African Nations (i.e., Zambia, Mozambique) and decided to migrate their existing systems to OMS over time. Tanzania has taken a similar approach to Namibia and simply migrated their pre- existing system to an on-line portal. A decision to move away from this towards a grid would be based on pressure from clients but there are no indications of a desire to do so at this time.

[1] In Australia several states were researched to determine if any of them were truly "no-grid", but all impose some sort of latitude – longitude grid, In Latin America Chile and Peru were looked at but Chile uses a UTM grid approach. Many other Latin American countries use a concession approach and do not really have "free miner entry".

Namibia has 20,000 tenure instruments (i.e., licenses) to manage, Tanzania over 100,000[2] and converting this much tenure would be cost prohibitive based on Ontario's experience (the Ontario representative stated that it took five years and three to four individuals to complete all the required Boundary Claim Reports. Greenland did not give significant consideration to other approaches (as opposed to migrating their existing paper-based system approach to OMS and did not consider a grid approach. As a late adopter, the NWT has access to more advanced technology solutions that make a no-grid approach more feasible but also is now aware of the true amount of time and resources required to implement a grid solution. The table below summarizes some of the advantages and disadvantages of the two approaches.

Table 1: Advantages and Disadvantages Summary

Approach	Advantages	Disadvantages
Grid	• Minimizes chance of future conflict. • Fixes absolutely the location of a claim. • Cells remain fixed forever, so anything recorded against a cell is permanently preserved. • Creates a very orderly arrangement of mineral title.	• Requires up front decision on grid coordinates, cell sizes. • Not reversible without extreme cost. • Requires conversion of legacy tenure, creation of various rules around existing tenure where multiple legacy claims intersect a single cell. • Inflexible on irregular boundaries - cells project into areas where issuance of mineral rights is prohibited again requiring creation of rules around what portion of costs of the partial cell clients must pay (100% in Nunavut, 50% in Ontario). • As boundaries of areas restricting mineral tenure issuance change the visual overlay of the grid would have to be constantly changed to avoid giving the perception of the ability to select mineral tenure. • Requirement for large amounts of training both for staff and clients.
No-Grid	• No requirement for conversion of legacy tenure results in quicker implementation, less resources. • The system will look familiar to clients especially if business rules for shape/size/orientation of claims are like existing ones for ground staking. • Irregular boundaries are respected with no cell projection or requirement for sterile areas adjacent to borders, etc. • Changes to boundaries of areas restricting mineral tenure issuance have no impact other than existing tenure has to be respected. • Business rules could be changed without the need to change an underlying arrangement of cells.	• Appears to be going against consensus favouring grid approach in Canada and Internationally. • Possibly more potential for conflict depending on coordinate system and ease of use for clients. • Appearance of cluttered tenure depending on number of vertices allowed to define tenure.

[2] "Cadastral Grids in Mining: Considerations When Implementing Cadastral Grids," Whitepaper (Cape Town, South Africa: Spatial Dimension (a Trimble Company), June 22, 2017)

In addition to the above considerations, there are specific geomatics considerations that need to be factored into a decision on an approach to OMS.

Table 2: Geomatics Considerations Summary

Grid	Both	Non-Grid
The conversion of legacy tenure to a grid implementation generally requires a pre-conversion period or time during which no applications for mineral rights may be made. This could be seen to reduce exploration activity and investment during this time The complexity of tenure converted to a grid implementation is highly related to the cell or unit size chosen for the grid. A larger grid size will reduce the complexity of the grid but will result in the loss of definition between the underlying geology and bounding mineral rights. Conversely, a smaller grid cell or unit size will increase the complexity of the mineral rights fabric, and allow for finer definition of mineral rights	The implementation or deployment of an OMS system appears to coincide with a greater than normal volume of applications for mineral rights. Performance improving techniques exist in web-based geospatial solutions although these are highly specific to the software and technologies employed. Data validation tools reduce the need for administrative capacity, preventing erroneous or invalid applications for rights in an OMS system. The data validation tools available are highly specific to the technologies and implementation of an OMS system. OMS systems built upon enterprise grade software solutions appear to have relative longevity in the market. Pre-defined software release schedules or product lifecycles aid in planning and remove organizational impediments.	From a geomatics perspective, the conversion process for legacy tenure in a non-grid system requires less work, as existing tenure can be represented in an OMS system without the need for change to the legal size and shape of the tenure. A non-grid or free form approach to OMS may allow the end user to digitize and create complex non-orthogonal polygons or features. The additional feature vertices required to define the extents of these polygons may require additional system resources at scale. This could be avoided by limiting number of vertices i.e., clients could select trapezoids that follow geological trends more closely.

The main conclusion of the research is that as opposed to spending too much time researching how other jurisdictions have decided between the two approaches (which do not seem to have been significant), the main policy objectives of migrating to OMS need to be defined and then an approach selected based on the advantages and disadvantages listed above. Currently, there are no substantive reasons why an OMS approach not using a grid could be adopted although it may be that the NWT is the first jurisdiction to undertake a process to decide between the two options. Given that other than the Yellowknife area most mineral rights are oriented N-S, E-W it may be that a no-grid approach to OMS favouring this orientation be adopted as that would simplify future “clipping” of new mineral rights to surveyed mineral leases. This would also simplify regulation drafting if claims were maintained at roughly the current size. An allowance could be built in allowing for non- N-S, E-W orientation shapes on application, as in Tanzania, this approach would have several benefits, including allowing the client to follow geological structures, only claiming what the client is interested in acquiring and avoiding areas that have been withdrawn.

The research leads ARC/AGL that, given the available technology allowing implementation of a no-grid system, the complexity and ever evolving network of areas that restrict the issuance of Crown mineral tenure, the time and resources required for conversion of existing tenure and the implementation of features of the Mineral Resources Act (MRA) such as “Zones” and “Restricted Areas”, a no-grid approach would be the best solution for the NWT. The lack of the requirement for tenure conversion and simpler regulatory drafting should allow for a more rapid implementation of OMS that will improve the overall competitiveness of the NWT mineral policy framework in a shorter time frame than if a grid solution is implemented. It is strongly recommended that ITI consult with existing or potential clients to determine what their preference is for a grid versus no-grid, or a combination thereof.

2. PROJECT BACKGROUND

The Government of the Northwest Territories (GNWT) Department of Industry, Tourism and Investment (ITI) completed work on the *Mineral Resources Act* (MRA) which was passed in the Legislative Assembly in August 2019. Powers under the MRA provide for online map staking (OMS) to be instituted in the Northwest Territories (NWT), modernizing mineral rights, and making the NWT contemporary with other jurisdictions around the globe. Research is currently under way to inform decisions to support implementation of elements of the MRA regulations and information system infrastructure development. In the NWT, OMS will be part of a larger data management system. OMS means an end user selects areas open for staking, pays for, and is awarded tenure (mineral rights) electronically, typically via the internet.

Historically, mineral rights in Canada have been physically located on the ground either using a series of posts defining a polygon or using a centre line with the mining right defined by a set distance either side of the centre line. The claims would be located on a map base linked to the jurisdictions topographic base, either a latitude and longitude system or Universal Transverse Mercator (UTM) grid. Prior to the widespread adoption of Global Positioning System (GPS) the exact shape and location of the claim was often not known until a legal survey of the perimeter was completed. As Geographic Information Systems (GIS) Technology and Internet access became easier to use it was recognized that the physical staking of mineral rights could be replaced with an online system allowing selection of mineral rights.

Restrictions associated with early web-based GIS systems (computational limits) resulted in the need to impose a cadastral grid on a jurisdiction with clients selecting pre-determined grid cells to establish mineral rights. Legacy tenure then had to be converted to tie into the imposed grid. As GIS technology improved, it became easier to implement OMS systems that allowed for the selection of free form polygons to define mineral rights; although a significant number of jurisdictions have established cadastral grid cell systems especially since United Nations organizations such as the World Bank supported the cadastral grid cell approach as best practice despite the limitations and complications such systems can create highlighted by Trimble in their 2017 White paper[2]. As the GNWT is a late adopter of OMS, it is in a position that it can select either a cadastral grid cell approach or a free form "non-grid" approach.

The current context of the NWT is best summarized in Figure 1 below which is a composite map of most of the areas of the NWT that have some sort of restriction around the issuance of mineral rights, varying from a complete restriction to various requirements for notification. For some of the areas highlighted, the responsibility for mineral rights issuance has been devolved to an Indigenous Government. While some of the boundaries of these areas have been surveyed by Natural Resources Canada (NRCAN), many have not and are defined by metes and bounds descriptions. Any OMS system adopted by the GNWT will have to handle all these very irregular features without mineral rights appearing to encroach on them. In addition to the above, the MRA includes regulation making authority for "zones" and "restricted areas" which are an additional layer of what could be very dynamic and shifting areas that any OMS system will have to deal with.

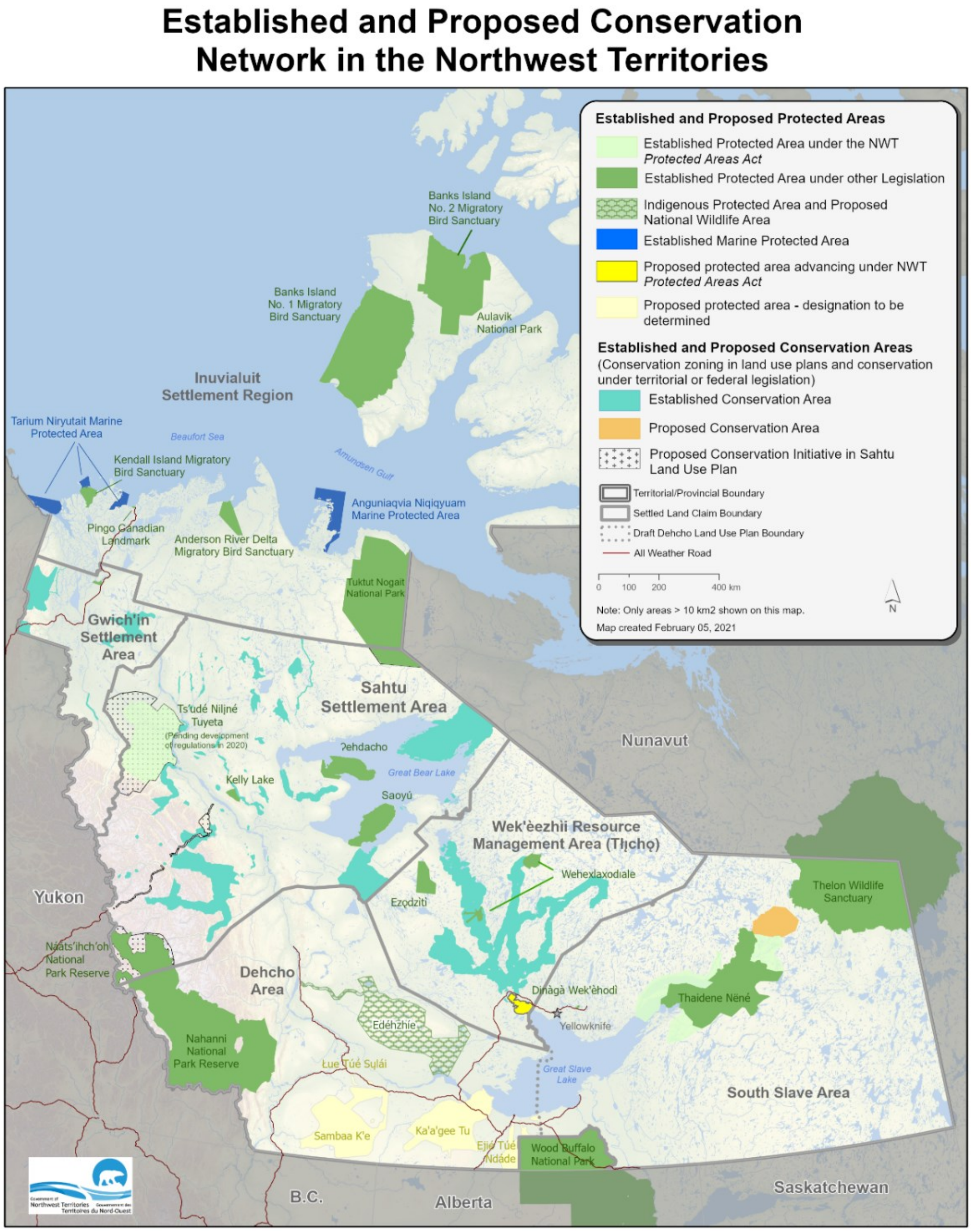

Figure 1: Map showing areas with restrictions on mineral rights issuance in the NWT.
Source: Canadian Parks and Wilderness Society Northwest Territories Chapter

The other aspect of the current situation in the NWT that an OMS system will have to be able to cope with is the current mineral rights dispositions (i.e., Mineral Claims and Mineral Leases). As Figure 2 below shows the current mineral rights in the NWT is dominantly a mix of Mineral Leases (issued for 21 years) and Mineral Claims (maintained by performing work that is subsequently filed for assessment credits), with a few prospecting permits. The Mineral Leases have been surveyed and the boundaries are set and cannot be changed. Figure 2 also shows that currently there are large areas of the NWT that do not have any significant Mineral Claims or Mineral Leases. This last point could be an important consideration in the selection of any system.

Implementing a no-grid system will be able to deal with the above relatively easily providing there are adequate tools to allow clients to "clip" their claims to the irregular boundaries. There may be a need to check the location of some older leases for the accuracy of their location in whatever coordinate system GNWT uses. Imposing a grid will create almost 800 "boundary claims" with two or more clients potentially in the same cell (see page 34 for detailed analysis) and will require dealing with cells projecting into any areas restricting mineral tenure issuance. This increases the amount of administrative work for during the transition and ongoing after implementation. The only mitigating factor is the relative lack of active mineral tenure in the NWT currently compared with past levels which lessens the amount of claim conversion required; however, this situation could change very quickly.

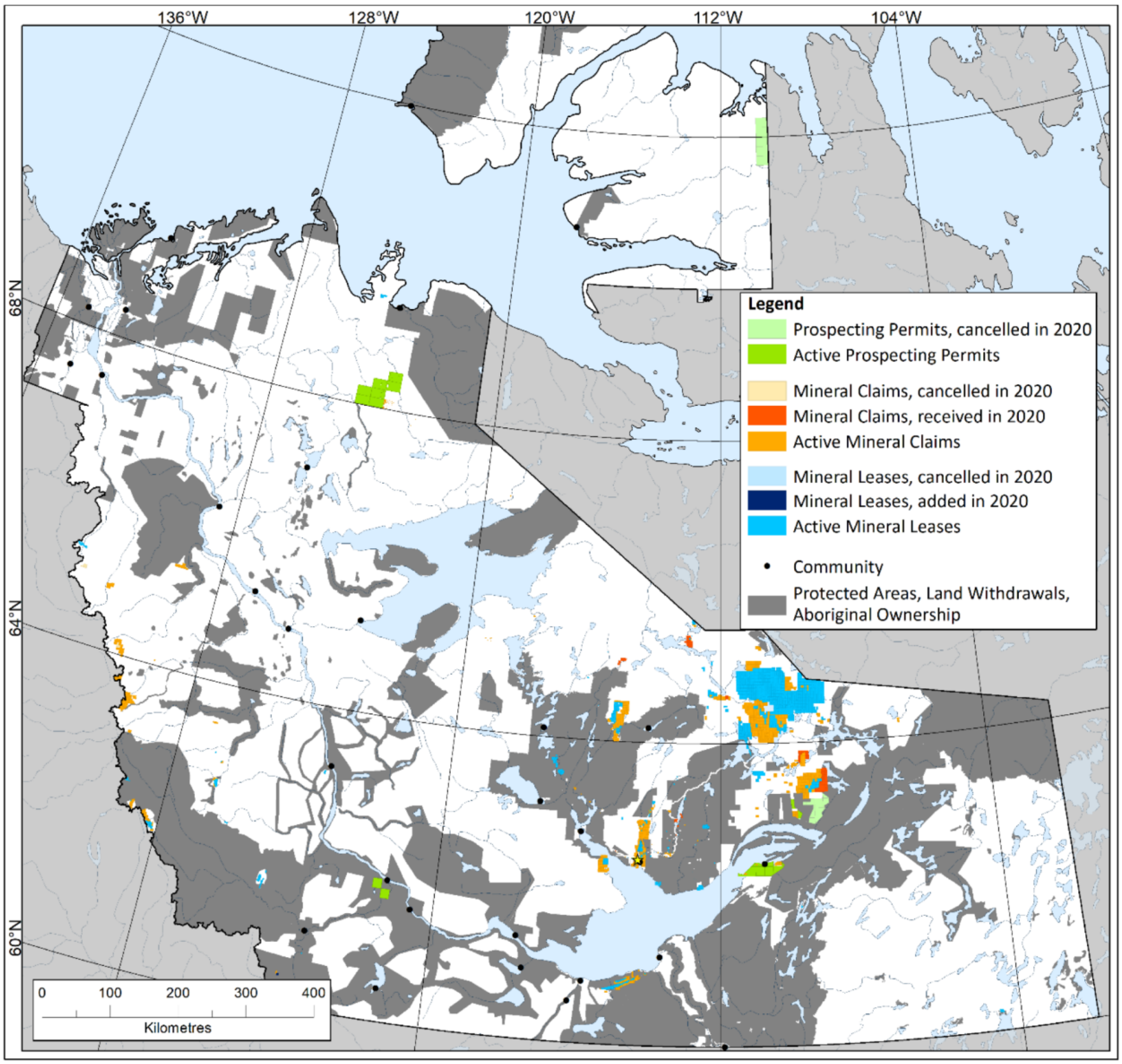

Figure 2: Mineral rights in the NWT as of 2020.
Source: NWT and Nunavut Chamber of Mines

3. JURISDICTIONAL SCAN

In conducting this research, three jurisdictions were selected that use grid systems and three jurisdictions were selected that do not use grid systems (i.e., no-grid systems). Scans of various areas with significant mining industries were completed including Australia, Africa, and South America. All the grid -based jurisdictions are Canadian and chosen because they match to some degree the geological context of the NWT and geo- political setting of the NWT although Nunavut is somewhat simpler with one single Land Claim Agreement. BC was not subject to the numbered Treaties as was the NWT (with the exception of the Inuvialuit) and as such faces a complicated situation of overlapping traditional use areas; however, there has been progress in advancing agreements (e.g., the Nisgaa). While Ontario has numbered treaties in place similar to BC there is a similar complex situation of overlapping traditional use areas with ongoing land claim processes. In addition, both BC, Ontario and Nunavut have ongoing land-use planning processes associated with various conservation initiatives that have interim withdrawals in place. The Ontario Mining Act modernization process is similar to the MRA process in that a large part of it was focussed on the interaction of mineral tenure issuance and mineral industry activity and the various Indigenous Governments and organizations in the province.

Selection of no-grid jurisdictions was more difficult as there is a paucity of examples that are truly "non-grid"[2] however Namibia and Tanzania were selected as two jurisdictions with no-grid systems that have extensive mineral rights issued and in the case of Tanzania have some geology similar with the NWT while Namibia has an active diamond sector. The mineral tenure maps of Tanzania reflect this to a degree with long narrow tenure on the coast reflecting the onshore and shallow offshore alluvial diamond deposits and non NS – EW tenure in Tanzania tracking narrow greenstone belts. Selecting a third jurisdiction that is truly "no-grid" was challenging as a number that were researched appear to be hybrid in that mineral rights are oriented and defined with reference to either UTM or Latitude/Longitude however rights are not based on selecting from a pre-determined grid of cells but on defined coordinates. Greenland was ultimately selected as a near non-grid system as irregular boundaries, such as the coast- line, can be used as part of the outline of the right and as a Northern jurisdiction Greenland faces the same issues as NWT with convergence towards the pole.

In completing the research to select jurisdictions, it appears that rather than a binary choice between a strict grid cell selection as opposed to a no-grid cell approach to selecting mineral rights, the reality on the ground is that the choice is about how much control a jurisdiction wants to impose on clients selecting mineral rights. The grid cell approach adopted by most Canadian jurisdictions to date is one end member in that mineral rights are based on selection of pre -defined cells with little discretion for the client other than the number of units selected up to a set maximum. At the other extreme is probably Namibia which allows for dynamic free form selection for mineral rights. In the case of Tanzania, the preferred approach is N-S, E-W oriented tenure based on latitude and longitude however clients can apply to acquire mineral rights that do not conform to these norms. In Greenland, latitude and longitude coordinates determine the mineral rights blocks however clients are allowed to "clip" to the coastline or irregular boundaries of areas where mineral rights issuance is prohibited. In the middle ground is probably the Australian jurisdictions where claims consist of a certain number of defined "graticules" (i.e., a set amount of minutes and seconds of latitude and longitude that are combined to constitute the claim) with a mixture of sizes for these graticules amongst the states. In effect, a latitude and longitude grid is imposed however cells are not picked. While there is not a grid propagated across the states (as in Canadian jurisdictions), the strict limitations make the system closer to a grid than either Namibia or Tanzania.

A questionnaire was developed in cooperation with GNWT officials to conduct interviews with the jurisdictions. Interviews were completed with five of the jurisdictions after extensive outreach through various approaches. The questionnaire is attached as Appendix A. Notes from the interviews are in Appendix B Overviews of the jurisdictions approaches to OMS are described in section 3 below.

3.1 Non- Grid Jurisdictions

Research did not find many jurisdictions with a "no-grid" approach to OMS. All Canadian jurisdictions have some form of pre- selected grid cell system. Many African and Latin American have converted to grid cell systems in the last few years as much of this work is funded by United Nations agencies such as the World Bank that see the grid cell approach as best practice. This was based on work by the World Bank summarized in a June 2009 report that covered all aspects of building a modern mining cadastre. Only a small portion is devoted to the actual selection of mineral rights with most of the report focussed on subsequent management of that right. The report does not discuss the advantages and disadvantages of the various approaches to defining mineral tenure and at no point discusses the issues around conversion of legacy tenure. It simply asserts that the cadastral unit (or grid cell) approach is the logical end point in the development of approaches to selecting mineral tenure digitally.

"One of the most innovative and efficient concepts introduced in the management of mineral rights is the cadastral unit (CU). A CU is a quadrangular polygon with constant (or pseudo-constant, depending on the type of projection used) dimensions that is referred to and has a fixed position within a system of coordinates. The definition of a CU should be included in any legal framework, and cadastral procedures should provide technical details about the delimitation of mineral licenses. Before the CU concept was developed, many countries had no restrictions on the shape, geometry, and position of mineral rights, leading to a number of problems, including frequent overlaps between adjacent concessions and the presence of areas (depending on the rules of each country) that were geometrically blocked for applications. The concept of a CU has been successfully introduced around the world under various names, including the cuadricula in Bolivia and Peru; the carré in Madagascar, Mauritania, and the Democratic Republic of the Congo (DRC); the bloco in Mozambique; and new CUs currently being adopted in Mongolia, Nigeria, Zambia, and many other countries

The final step in the evolution of a modern CU was the requirement that polygons corresponding to mining licenses and mineral rights cannot float and be placed anywhere. Rather, they must always be located coherently within a predefined and standard grid (see Figure 6). These grids can be mining specific (exclusively designed for the mining cadastre) and drawn over national maps, as is the case in Bolivia and Peru, or they can be generic, using the standard grid that is usually represented in topographic maps, as in Madagascar, Mauritania, and Mozambique".[3]

More recently this approach has been questioned based on the complexity in converting legacy tenure and issues with the creation of "sterile" areas proximal to sensitive border areas and adjacent to surveyed legacy tenure that cannot be converted. Feast (2018)[4] discusses the issue in a presentation. In this paper, the author challenges some of the presumptions that have led jurisdictions to assume that a grid approach is best practice. In the quoted text below the assumptions of World Bank officials are questioned (in bold italic).

World Bank Book: Mineral Rights Cadastre. Jun 2009 One of the most innovative and efficient concepts introduced in the management of mineral rights is the cadastral unit (CU). ***The real advance is the in implementation of modern mining cadastre systems together with updated survey techniques using GPS technologies***

Before the CU concept was developed, many countries had no restrictions on the shape, geometry, and position of mineral rights, leading to a number of problems, including frequent overlaps between adjacent concessions and the presence of areas that were geometrically blocked for applications. ***Modern mining cadastre systems will prevent overlaps no matter what shape a licence is. So why then force a simple polygon to fit a complex cadastral grid?***

[3] Girones, E. O., Alexandra, P., & Gotthard, W. (2009). Mineral Rights Cadastre: Promoting Transparent Access to Mineral Resources (No. 48609; Extractive Industries for Development Series #4, pp. 1–96). The World Bank. http://hdl.handle.net/10986/18399,

[4] Feast, B. (2018, February). To Grid, or not to Grid.

Enrique Ortega: "Design and Supervision of Installation of Mining Cadastre System Phase I Report. July 2014" The best practice solution for the optimization of land-use for mining activities, and for facilitating the management of a Mineral Rights Cadastre, is the establishment of a cadastral and the Cadastral Unit (CU). ***Best practice or subjective opinion?***

It is obvious that if the CU has small dimensions, its adaptation to the geometry of the pre-existing licenses (and consequently the transformation of the current titles to the new system during the transition period), is easier. ***The smaller the CU, the more complex the transition and later management of existing and new applications especially for adjacent title***

In summarizing, Feast makes the following points.

- *We have been involved in numerous projects where Governments have wasted an inordinate amount of time, resources and goodwill in trying to implement a cadastral grid for no good reason and simple blind faith in someone's opinion of best practice.*
- *Governments should focus on streamlining the sector not undertaking superfluous activities that jeopardise security of tenure and create disputes that end up in the judicial system.*
- *The truths about cadastral units.*
- *You can not convert adjacent licenses without violating security of tenure.*
- *Small grids do not make it easier for applicants.*
- *Grids do not make it easier for mining cadastre systems.*
- *Grids do not make it easier to identify boundaries in the field.*
- *A justification for large grids for exploration / reconnaissance licenses can be made but trying to accommodate large scale and small-scale mining within a cadastral grid is a pointless exercise.*
- *Grids do not provide any real return on investment.*

Feast works for Trimble, a company that has supplied mining cadastral support to numerous jurisdictions, both grid and no-grid approaches, so are aware of issues created the grid approach. The only time Trimble recommends a grid approach is where there is very little existing tenure to be converted.

Two jurisdictions in Africa stand out as good examples of non-grid approaches.

3.1.1 Namibia

Namibia has an active mining sector and modernized its mineral rights approach recently. Namibia uses a unique coordinate system (Bessel 1841), and this presented a challenge in that custom transformation parameters were needed to implement the system.

Based on the interview with three staff of the Namibia Ministry of Mines, it appears that the Namibian system is a work in progress and because of this there are still limitations largely due to lack of funding to complete the various modules within the Landfolio system being used. Namibia has chosen to move the system in use for many years over to OMS without implementing a grid cell overlay. Oil and Gas licenses are based on pre -selected blocks; however, Namibian officials determined that this was not suitable for mineral interests. The Namibian officials did not state why they didn't originally implement a grid approach similar to several other African jurisdictions however they did indicate they are in constant contact with other countries. Given that they stated when asked if they would consider moving to a grid that cost and complexity of tenure conversion would be prohibitive it is fair to assume that through conversations with other countries they have learned of problems encountered.

Figure 3 below is a map showing a summary of current mineral rights in Namibia along with protected and environmentally sensitive areas. Namibia has an active mining sector (with a significant alluvial and offshore diamond production sector), as demonstrated by the large number of rights on the map and therefore is a good comparison jurisdiction; however, the underlying geology is not as comparable to the NWT as other jurisdictions. The rights are a variety of shapes, orientation, and sizes. During the interview it was indicated that there is not even a restriction of the number of "vertices" or size for polygons selected by clients. It clearly shows a much more complex mix of polygon shapes than the NWT. Even the historic

Mineral Claims and Mineral Leases in the Yellowknife area do not show the amount of complexity that some areas of Namibia show.

As discussed above, Namibia is still finalizing implementation of the system and as such clients create their own shape files and either email them or bring them into the office. The final module allowing for true on- line selection has yet to be implemented due to lack of funding. When questioned if they had thought about a grid cell system, they indicated that this would be difficult and very expensive because of the complex geometry of current mineral rights and that they do not anticipate moving in that direction. Two of the issues they have right now are:

- Their system lacks a true "clipping" tool available to clients. Much of the work eliminating overlaps into restricted areas is completed by government staff although rights are clipped exactly to irregular boundaries.
- Related to the lack of clipping tools is that when clients select polygons slivers can sometimes be created between rights that can then be selected by other clients (they referenced "chair stakers" who acquire these slivers in the hope that adjoining claim holders will want to purchase these areas of ground but have no intention of working the ground). Namibia is looking at a combination of the clipping tool plus amending regulations to impose minimum claim sizes to deal with this issue.

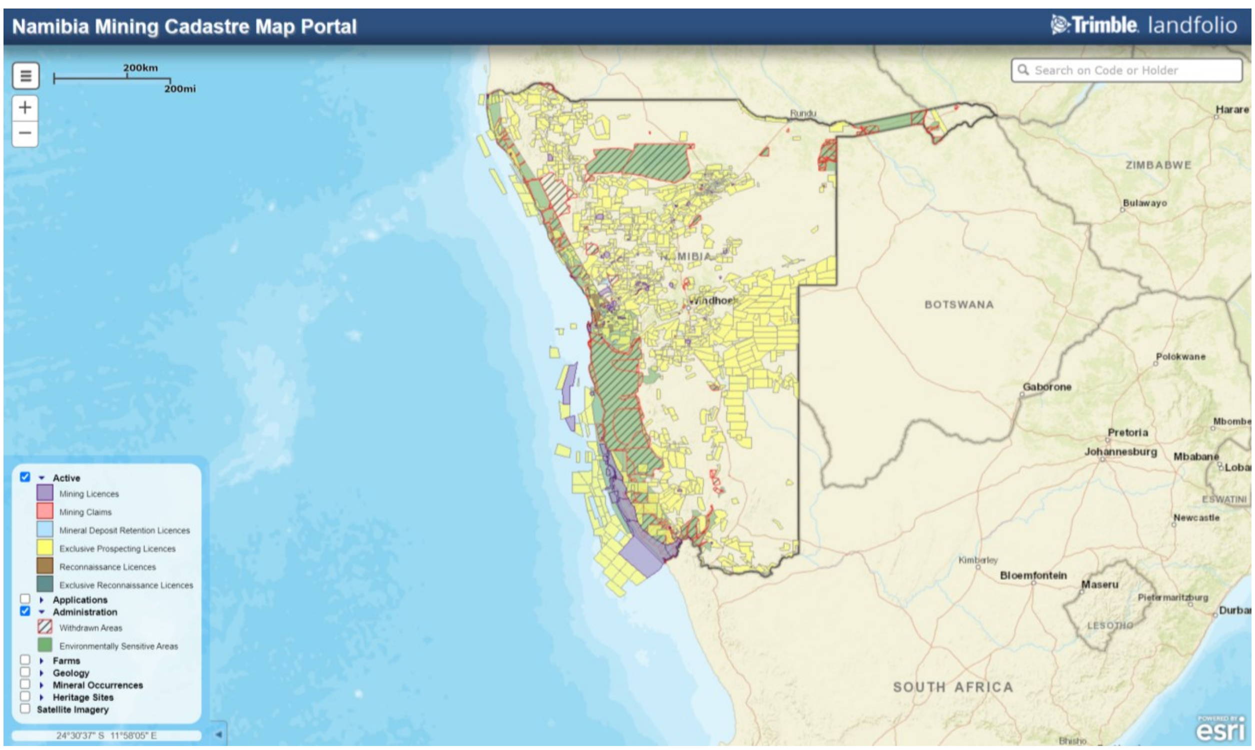

Figure 3: Namibia Mining Cadastre
Source: Government of Namibia Website

Figure 4 below is a zoomed in image of a portion of Figure 3 showing in more detail the varying orientation of the mineral rights and how there are no sterile areas adjacent to environmentally sensitive areas. While the shapes appear to be complex, they generally do not have many vertices (i.e., corners).

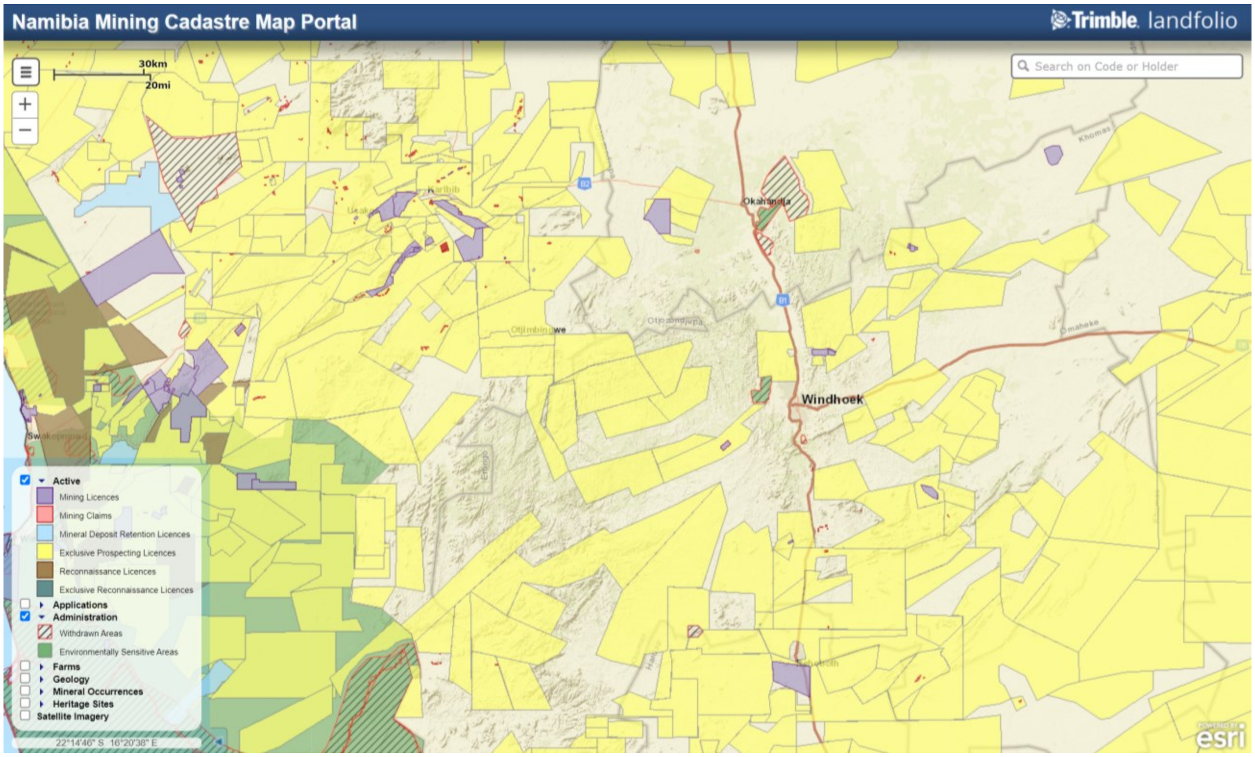

Figure 4: Detail from the Namibian Portal which shows that users can enter coordinates or choose to enter the shape dynamically.
Source: Government of Namibia Website

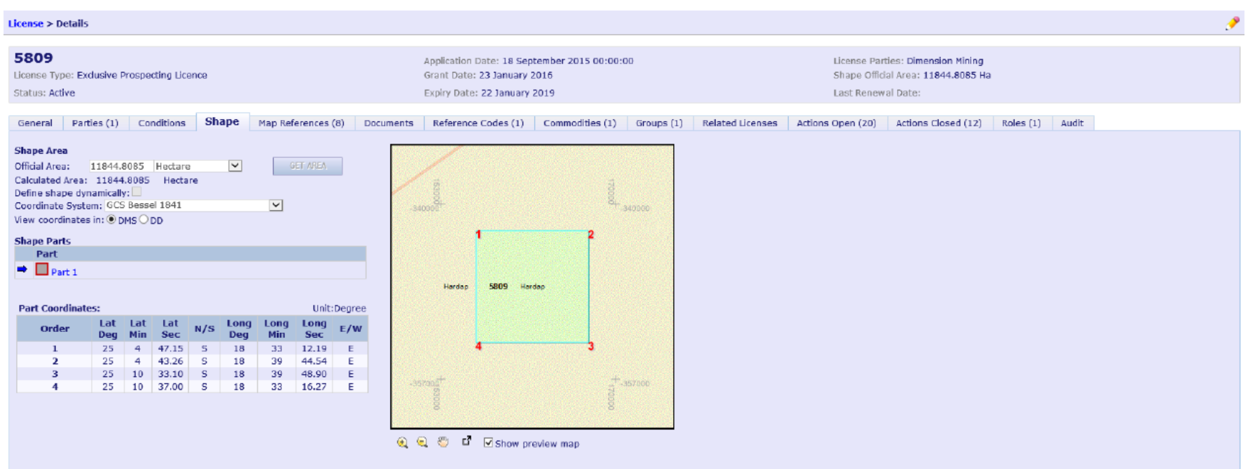

Figure 5: Data available on Namibian website for each mineral claim[5].

The Namibian approach is interesting in that they are attempting to move their pre-digital system of mineral rights into the digital world without, as discussed above, the cost and conversion issue associated with introducing a grid cell system. The Namibian officials interviewed admitted that while industry is appreciative of only having to select the areas they are really interested in; administratively, the lack of an accurate "clipping" tool and some rules on mineral rights size is causing problems.

[5] Maletzky, M., & Brumfitt, I. (2018, February). Project overview of FlexiCadastre/Landfolio in Namibia.

If the NWT was to follow a Namibia approach the first question would be - how free form will tenure polygons be allowed to be? Clearly, Namibia is encountering some problems because of this and is considering imposing some sort of rules around the shapes however because of the variety of shapes and orientations this may be difficult to implement. The Canadian Trade Commissioner for Southern Africa did indicate that he has heard a lot of favourable comments on the Namibian mineral tenure system from industry.

3.1.2 Tanzania

Tanzania has an approach similar with Namibia where clients define the area of interest on- line and submit this along with payment. The tenure is not automatically granted but is reviewed by officials in the "back office" before being formally approved (which in some ways is similar to the current gap between the initial pending claim and final approval although it was not clear to what extent any consultation with other users is undertaken). Areas are selected using latitude and longitude coordinates, subject to rules as set out in the regulations. Tanzania has adopted a similar approach to Namibia in that they have migrated a pre- existing paper system to an on-line environment (it wasn't clear from the interview if any physical on the ground "staking" was in play at some point). There does not appear to have been any consideration to move to a grid- based system when the current system was developed in 2014, although reasons for this were not explicitly stated. Tanzania started moving towards an OMS approach in 2005 so it may be that by the time the World Bank started promoting the grid approach Tanzania already had too much legacy tenure that would have made the conversion process costly.

Figure 6 below shows the current outline of mineral rights in Tanzania along with the major national parks (e.g., Serengeti). As can be seen, while Tanzania does not show the same degree of free form polygons as Namibia, there are areas where mineral rights are clearly not following a strict N-S, E-W orthogonal grid. The underlying geology of Tanzania shares some similarities with the NWT, particularly the Tanzania Craton and its narrow variably oriented greenstone belts.

Under the Tanzania mining legislation, a N-S, E-W orientation of mineral rights is preferred, however companies can select different shapes if there is supporting rationale. The quote from a Trimble white paper from 2017 summarizes the approach of Tanzania[2].

As a penultimate example, [Figure 6] depicts a screen shot from Tanzania's mining cadastre system. Note that parks and game reserves are shown in light green. Tanzania has tens of thousands of large scale and small-scale licenses. They encourage a north/south, east/west alignment of rights, but have not implemented a cadastral grid.

While Tanzania does not share the same geopolitical environment in terms of land claims as the NWT, it does have underlying land conflicts between formal mining and agricultural/informal mining interests which mineral rights issuance needs to account for. It does share the NWT issue of large National Parks and with irregular boundaries. Survey accuracy for agricultural parcels and small -scale mining activity is much less defined than for the larger mining company tenure which can cause problems with mineral rights issuance.

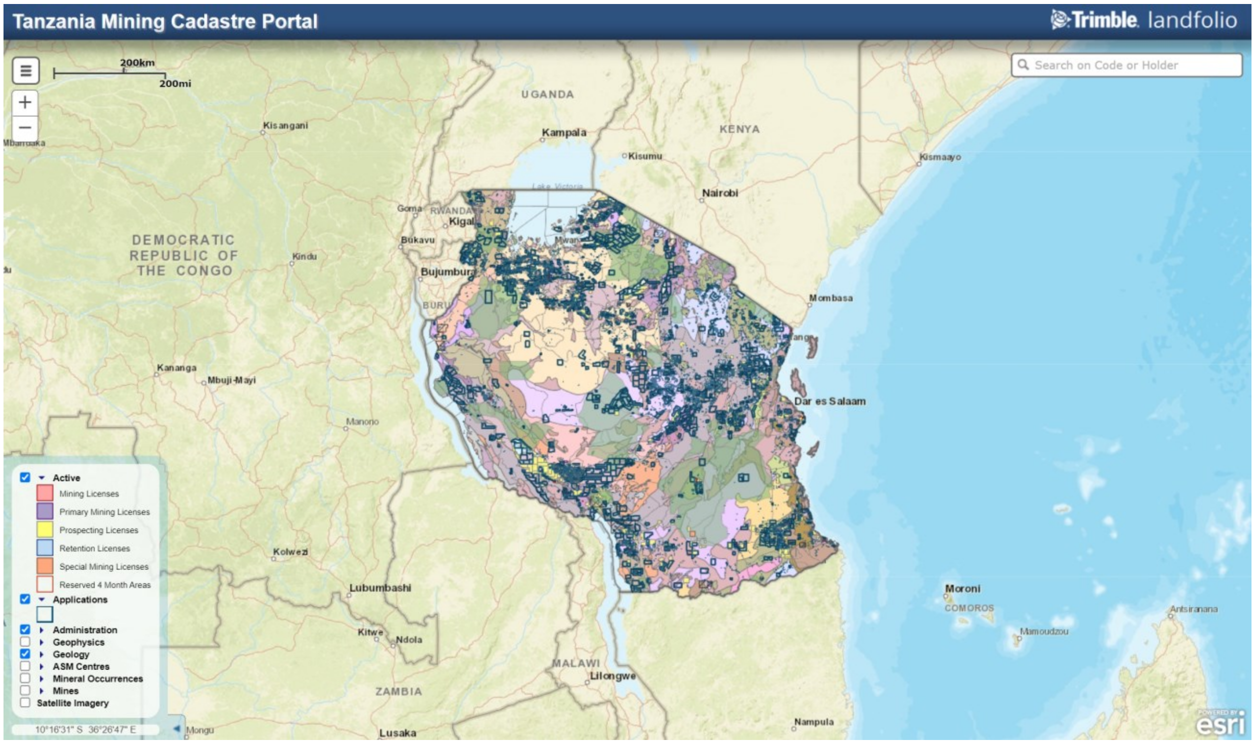

Figure 6: Tanzania mineral rights, parks, game reserves, and geology.
(parks and game reserves are shown in light green)
Source: Government of Tanzania Website

While it appears that some portions of the parks and reserves allow for mineral rights within their boundaries, in other cases, the mineral rights adjoin the park boundaries without any overlap. The allowance for free form polygons enables this approach. Figure 7 below shows an area of Figure 6 in more detail showing some of the free form polygons.

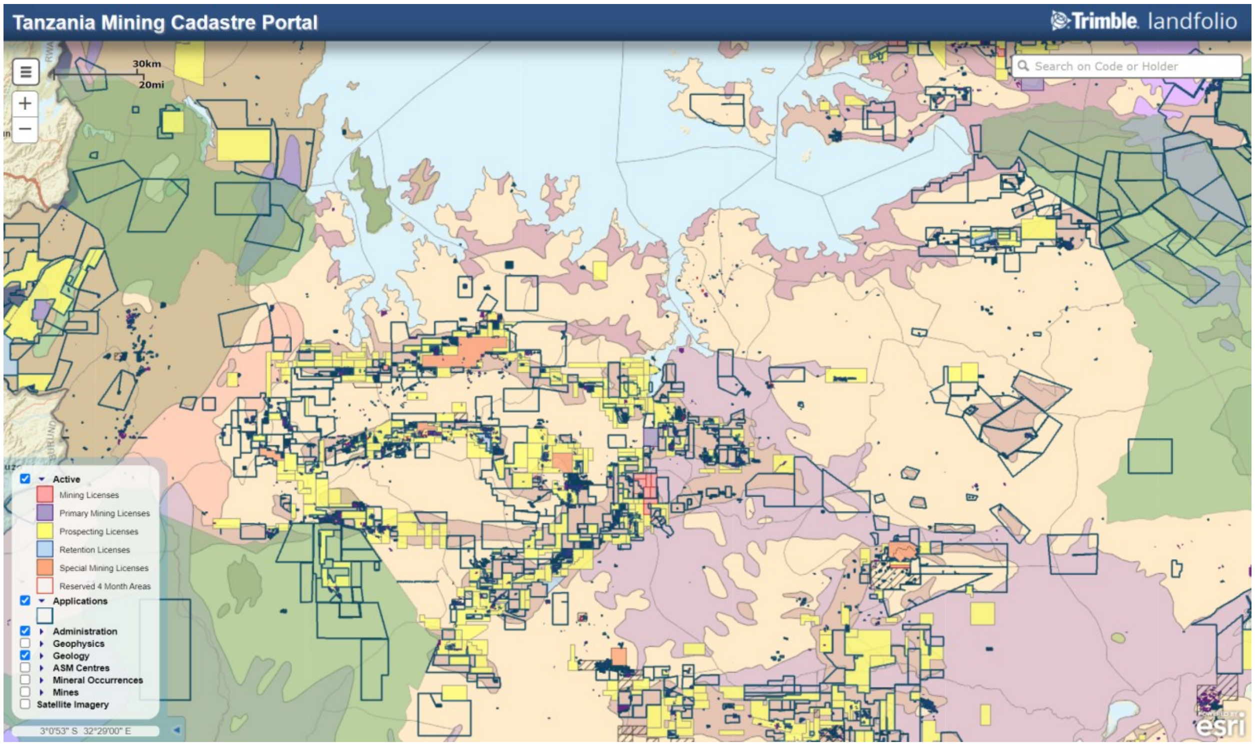

Figure 7: Detail of a small area within Figure 6

Figure 8 below shows that defining the area is limited to coordinate entry with an administrative process in place to deal with requests for rights not conforming to N-S, E-W orientation.

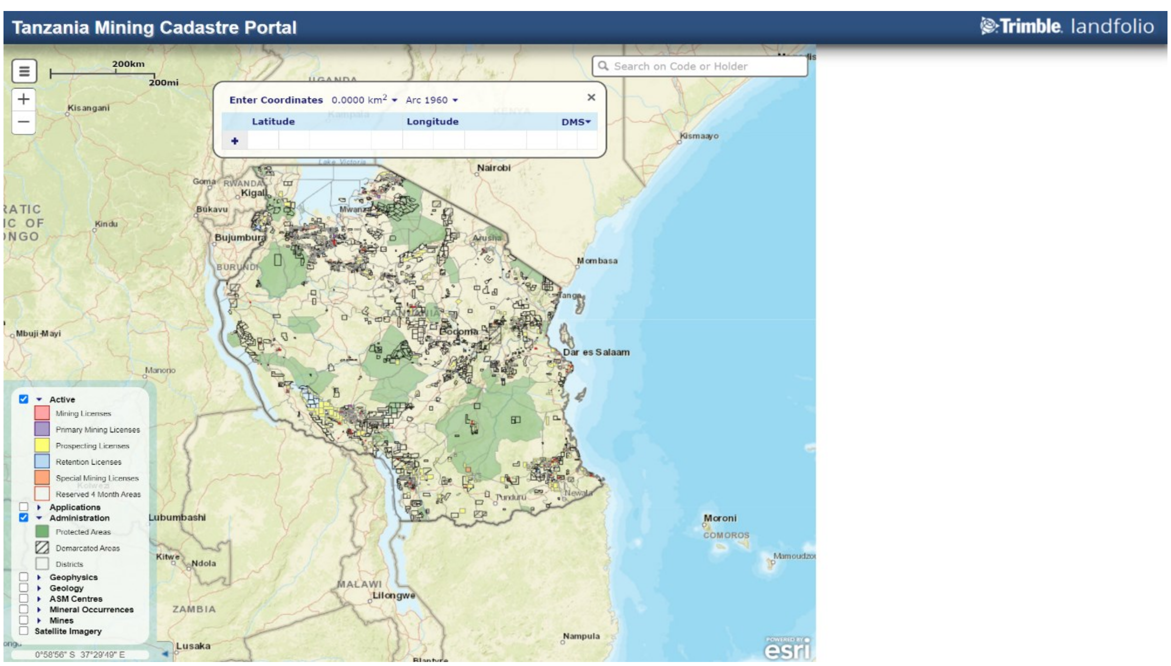

Figure 8: Tanzania Mineral Cadastre Portal showing lack of toggle switch for free form drafting as with Namibia.
Source: Government of Tanzania Website

Tanzania has not examined the possibility of moving to a grid cell system similar to those adopted by neighbouring Kenya and Mozambique. Although it was difficult to draw out a clear answer, it appears that this is in part based on the frredom that their no-grid system gives clients to select ground that closely matches the geology they are interested in. They do get some conflicts although clients are supposed to check if areas are open before selecting coordinates. Mineral tenure can be selected in game preserves, parks etc., but authority for undertaking activity is granted by the authority managing the particular preserve/park so mineral tenure does not have to clipped to the boundaries.

The Tanzanian official interviewed indicated that they would not consider moving to a different approach unless there is some pressure from clients to do so. At the present time, there is no pressure for any move towards something like a grid cell approach so it can likely be assumed that clients are happy with the current approach.

3.1.3 Greenland

Greenland mineral rights acquisition is based on selection of areas as defined by corners using latitude and longitude. As such, it could be considered a hybrid grid -based system however does not require the selection of pre- defined grid cells as per a true grid system. It is also allowed to use the coastline as part of the right boundary which will create an irregular boundary and tenure can be clipped to areas where tenure issuance is restricted. Other than this exemption, clients are restricted to NS – EW orientations.

206. The licence area shall be delineated as follows: a. The corner coordinates of the area will be defined by degrees and undivided minutes connected by lines of longitude and latitude. Longitude shall be defined in degrees West of the Greenwich meridian, latitude in degrees North of the equator. b. An area may, however, wholly or partly be delineated by the coast- line provided this is approved by BMP. Coast lines will be based on maps in one of the two series indicated in section 209. c. Corner points will be numbered clockwise starting in the upper left corner of the licence area. d. A licence area shall be at least 5 km2.[6]

Figure 9 below is a screen shot of the Minerals and Petroleum Licence Map of Greenland focused on a portion of Greenland showing an area of active mineral rights. The tenure blocks are mostly composed of blocks following lines of latitude and longitude which are not quite as free form as Namibia or Tanzania hence they have a blockier appearance although there is no predefined cell selection, only coordinate selection. A particular challenge noted by the Greenland official was the convergence of lines of longitude in the northern reaches of Greenland.

[6] Application Procedures and Standard Terms for Mineral Exploration and Prospecting Licences in Greenland, Ref. No. 69.03.10+01 Standard Terms for Exploration Licences for Minerals (Excluding Hydrocarbons) In Greenland § 206.

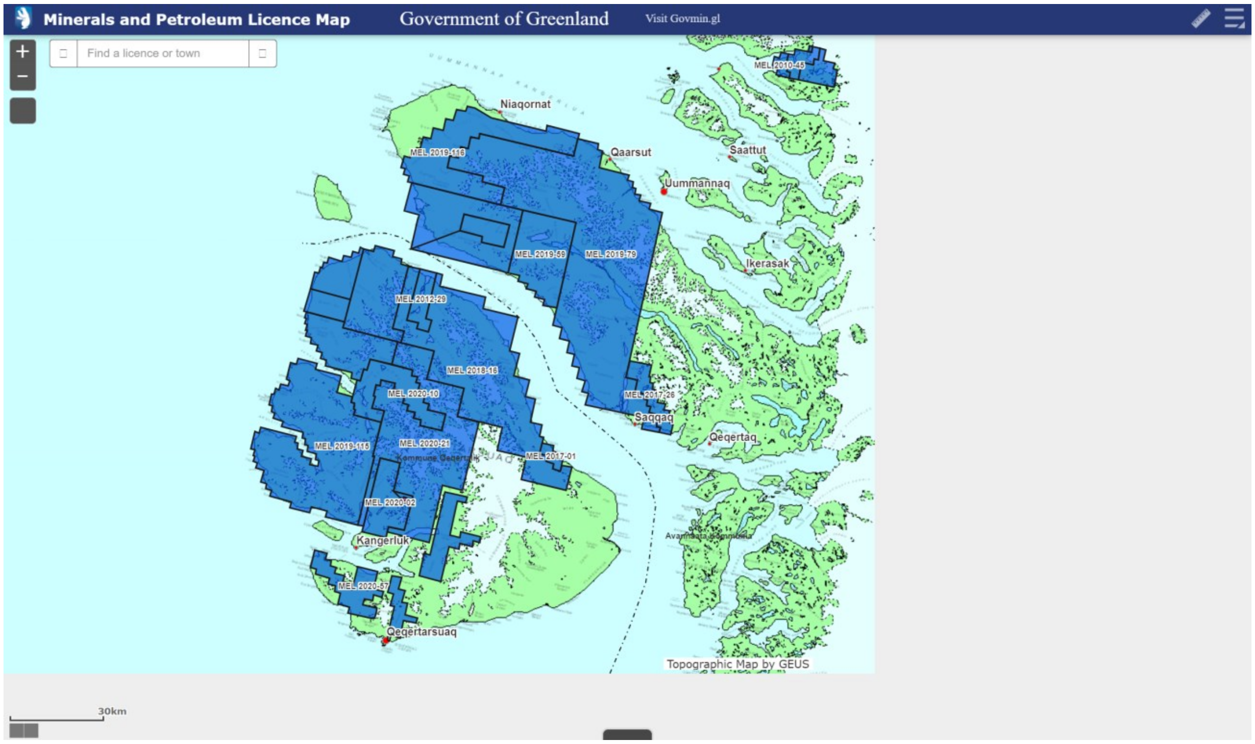

Figure 9: Screen shot of area in Greenland depicting an area of active mineral rights.
Source: Government of Greenland Website

The system Greenland is using is simply an improved version of what existed before (i.e., there was no decision process around selection of a grid or no- grid system) although by maintaining the status quo it could be assumed that a conscious decision was made not to implement a grid although this was not explicitly stated by the representative from Greenland during the interview. Acquiring mineral rights in Greenland has always been using latitude and longitude coordinates with no predefined grid cell selection. The new system allows users to select areas with a map interface as opposed to listing the coordinates in an excel spreadsheet and submitting these to the Government of Greenland who transcribed these to a map, a somewhat arduous process prone to errors.

3.2 Grid Jurisdictions

Three jurisdictions within Canada were selected based the following criteria:

- A mixture of jurisdictions that chose mandatory and voluntary conversion of legacy claims.
- Some similarities to the geo- political context of the NWT i.e., presence of large parks, protected areas and Indigenous Government titled lands where issuance of Crown mineral titles is prohibited.
- Large areas of contiguous legacy claims requiring conversion.
- Issues with the acceptance of issuance of mineral rights with communities, Indigenous Governments, and organizations.

3.2.1 Ontario

Ontario uses a latitude/longitude derived grid cell approach for selection of mineral rights (claims) selection. Legacy claims were subject to mandatory conversion to the new grid prior to implementation. The underlying geology has similarities to the eastern NWT Precambrian geology. Ontario also shares some similarities with the NWT in that the OMA emphasizes consultation and information sharing with Indigenous Governments and organizations that has created conflict in several instances. There has also been an ongoing land use planning debate around the creation of conservation areas that would restrict issuance of mineral rights over large areas. The two figures below illustrate the structure of the Ontario mineral titles grid including the cell block sizes.

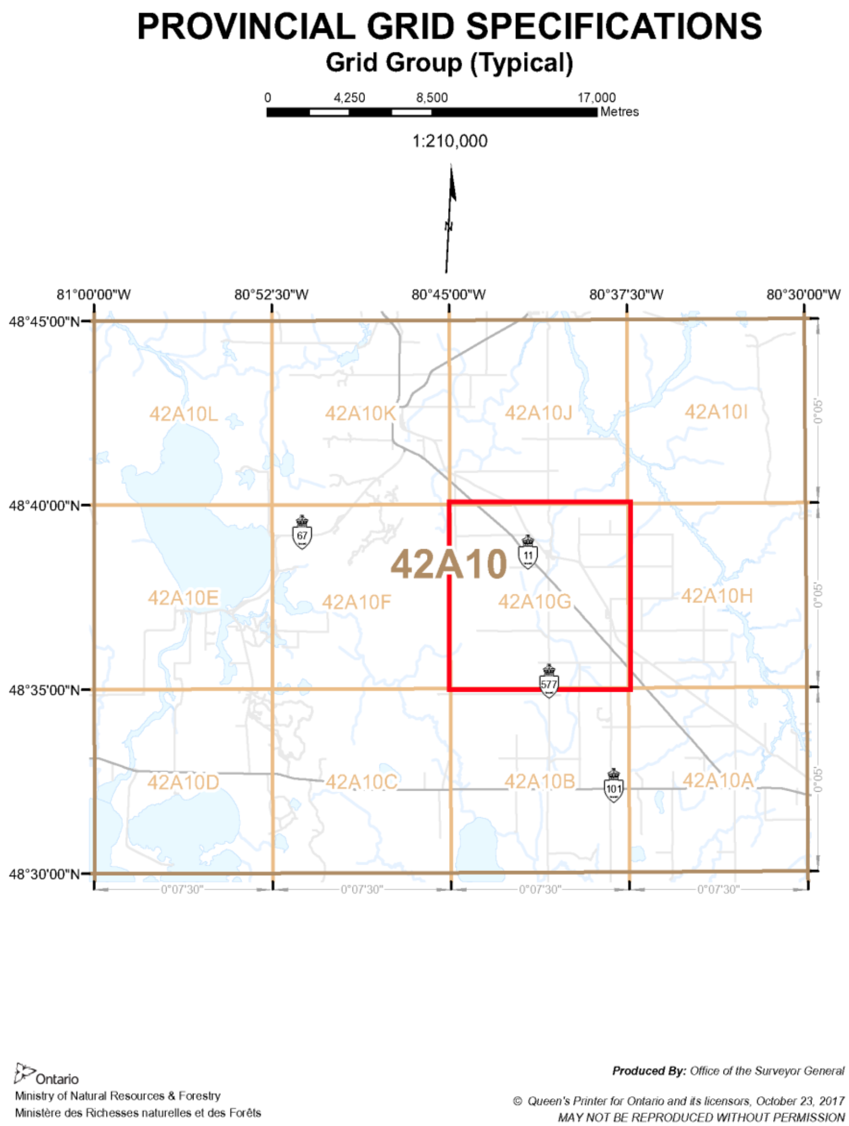

Figure 10: Ontario Grid Group.
Source: Government of Ontario

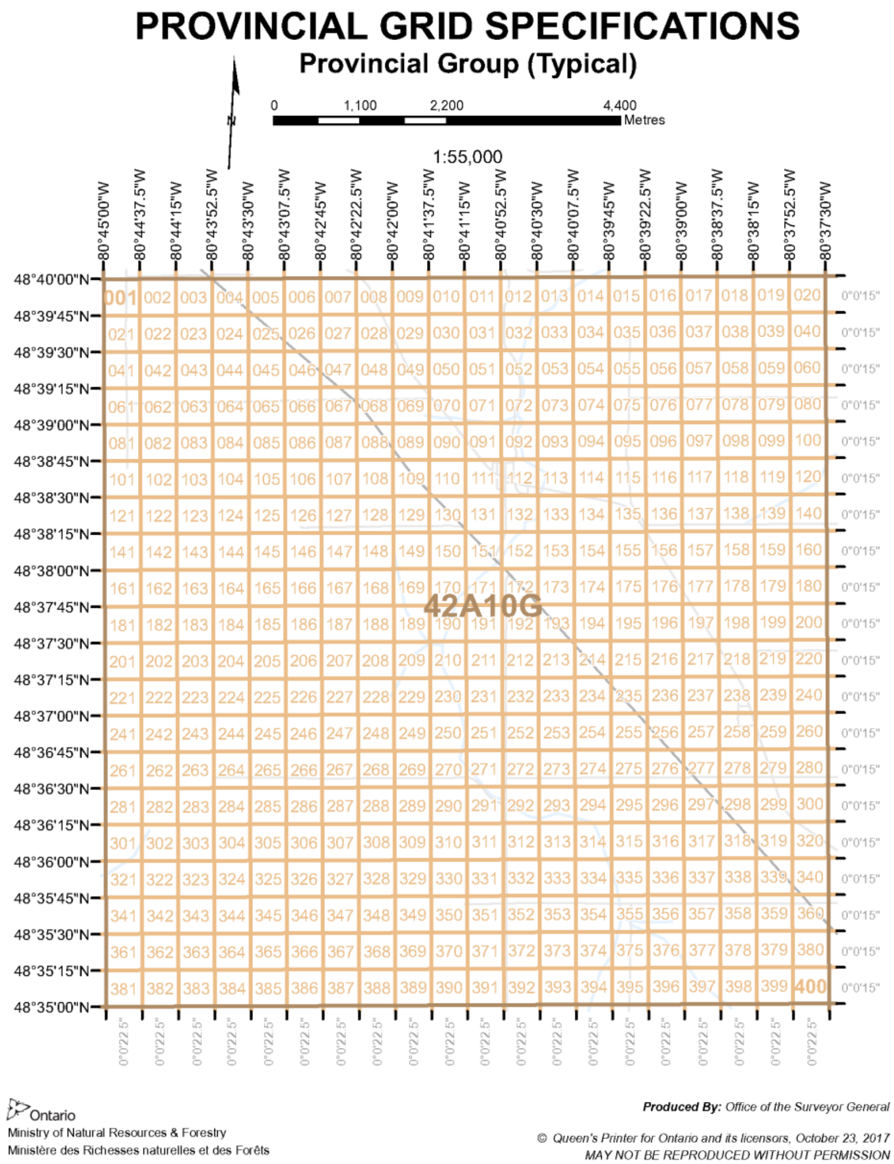

Figure 11: Ontario individual grid cells for claim selection.
Source: From Figure 10

Figure 12 below demonstrates the complexity of the Ontario mineral rights cadastre, showing the regularized grid overlain on the Kirkland Lake area with its complex pattern of historic mineral rights like the Yellowknife area. None of these mineral rights have been converted as they are similar to the mineral leases in the NWT with the difference that some have surface rights associated with the mineral rights.

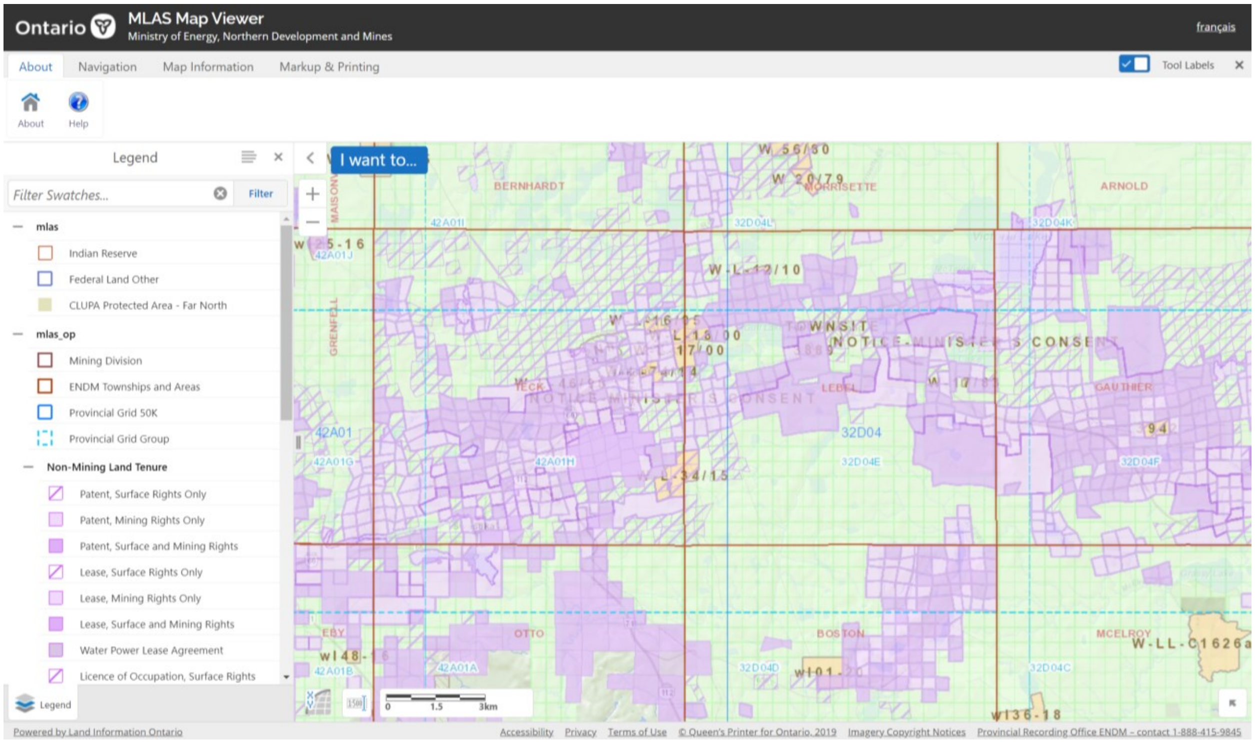

Figure 12: Regularized grid overlain on the Kirkland Lake area with a complex pattern of historic mineral rights.
Source: Government of Ontario Website

A very detailed interview was conducted with Ontario officials and most of the discussion below is based on this interview along with some open- source information available on the internet. Quotes from the notes to the interview are in italics in the discussion below.

At no time did Ontario consider a non-grid approach, "*at no time was there ever an option of going back to a map process*". The provincial oil and gas grid was looked at as an option but was rejected. It appears that technology selection partially drove this decision as "*the technology worked a lot better with a grid as opposed to weird shaped polygons*".

Ontario converted all mineral rights over several years. At the start of the conversion process there were 32,000 claims active in Ontario. The process involved the review of all claims on a township basis and the creation of claim boundary reports to resolve issues of conflict within and between individual cells and surveyed tenure. This was time consuming (5 years) and resource intensive; however, ultimately all issues were resolved with no remaining conflicts. There was a staking moratorium imposed for leading up to implementation. On going live, there was a significant amount of activity, partially driven by the restriction leading up to going live, although activity has remained at increased levels compared with the prior ground staking era because of the lack of the requirement for costly ground staking. The claim boundary process does result in the creation of sterile areas when one or more claims in a cell with several different claims lapse. The lapsed area cannot be selected until the entire cell is available. Some of these situations have been resolved by mergers between the other claim holders to create single ownership of the entire cell. Ontario developed a client guide to the conversion process: https://www.mndm.gov.on.ca/sites/default/files/claim_holders_guide_to_conversion_en.pdf

This document, a total of 18 pages, shows that the conversion process to get to a grid cell system can be a complex undertaking requiring considerable resources and time depending on the number of active mineral claims.

Ontario officials stressed the need for effective ongoing discussion with industry throughout the process and taking advice where warranted. Training of staff is equally important as training of clients. It does not appear that Ontario consulted with clients on merits of the grid vs another approach – the decision to move to the grid was an internal decision although the overall idea of moving to OMS was discussed with clients because of the impact on individuals and companies earning a living from ground staking.

The interview with Ontario and associated internet research demonstrates the commitment of time and resources required to successfully implement an OMS system that works with minor issues upon implementation. While NWT does not currently have the same number of active mineral rights as the 32,000 Ontario mineral claims, conversion would still take considerable effort.

If NWT was to adopt the Ontario approach, mandatory conversion would be required which would require resources. The analysis in geomatics below suggests a minimum of about 800 impacted tenures (dependant on selected grid cell size – it may be more) would have to be resolved. Further, various stakeholders would want to ensure that the "grid" did not visually propagate across areas with restriction on Crown mineral tenure issuance.

3.2.2 Nunavut

Nunavut is one of the most recent jurisdictions in Canada to convert to OMS following a lengthy process of over a decade since the idea was first proposed. Nunavut uses the same grid that is used for selection of oil and gas rights in Northern Canada (i.e., the oil and gas grid), although the grids main purpose is to define very large blocks of ground for bidding purposes. In preliminary discussions with local stakeholders, the oil and gas grid was noted as being "problematic in terms of incorporating surveyed leases that required some complex mathematics."[7] .

The grid of units used for map selection is described in Schedule 3 of the amended Nunavut Mining Regulations *(2020). It is identical to the grid described in the* Canada Oil and Gas Land Regulations*. The minimum size of a claim is one unit of 15 to 25 hectares. The size depends on where the unit is located in the territory. The average size of a unit is 18 hectares. The most a user may select is 100 units. The grid used for the online map selection of claims in Nunavut is available on the Nunavut Map Viewer.*

[7] Personal communication, Bruce Hewlko

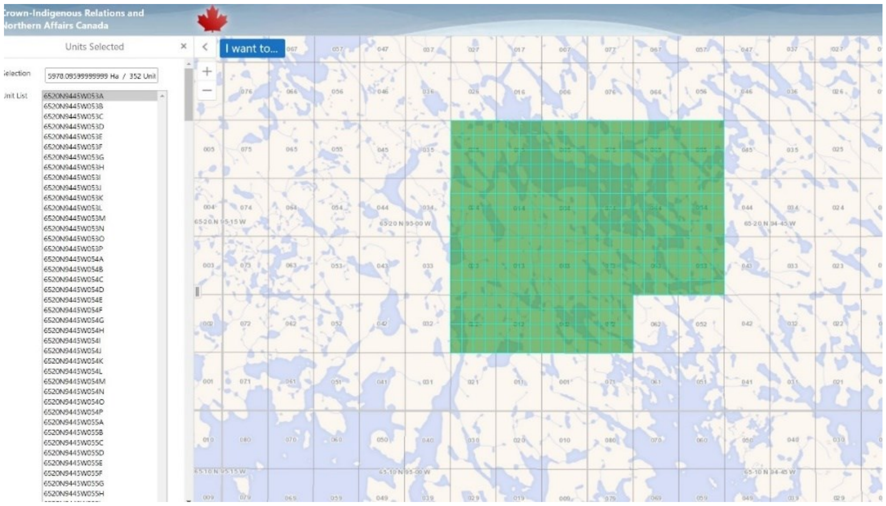

Figure 13: Nunavut Map Selection Portal.
Source: Government of Canada, CERNAC Website

Nunavut adopted mandatory conversion of legacy claims. Similar with the NWT, Nunavut has a substantial amount of legacy mineral leases that are not subject to conversion. Figure 14 below (from the Nunavut map viewer) illustrates the mineral rights around Rankin Inlet where there are Inuit Owned Land (IOL parcels) that have their own mineral rights selection criteria.

Nunavut Map Viewer

Expand/Minimize Map. This will open a new window.

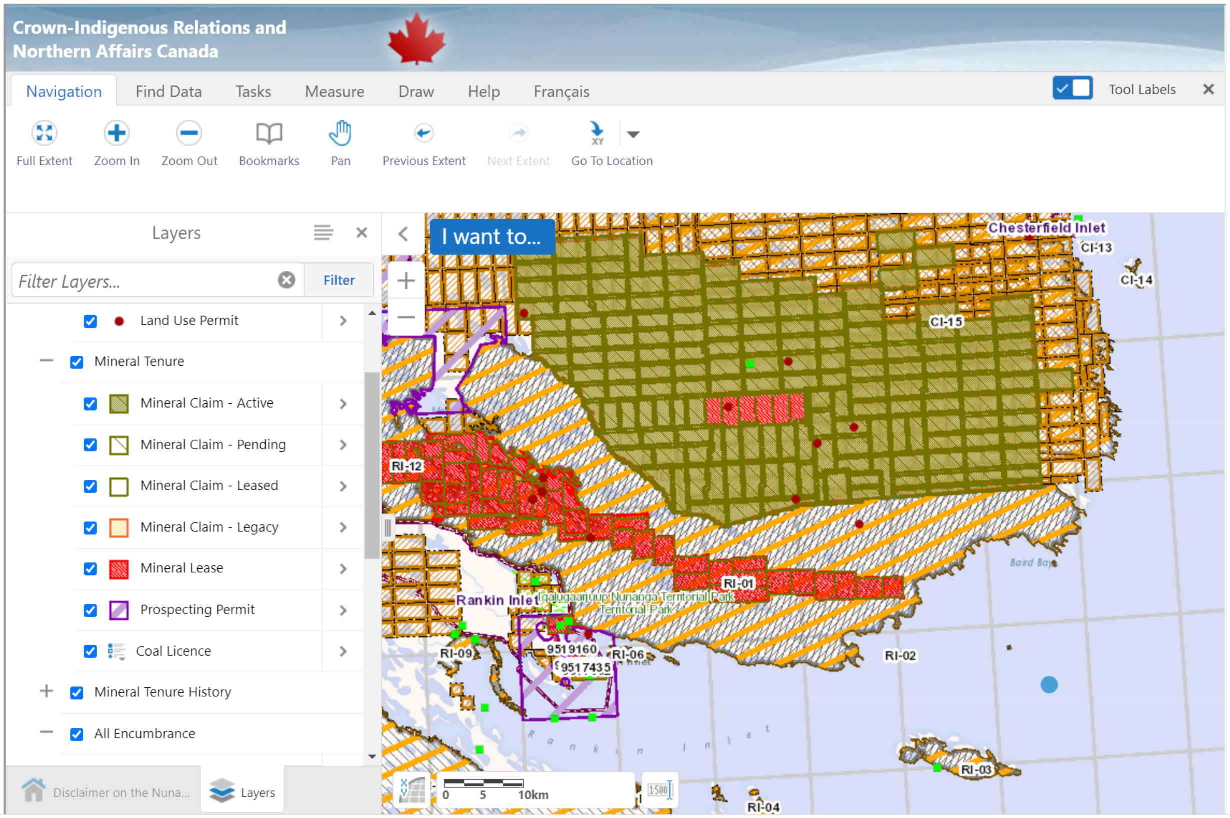

Figure 14: Nunavut grid layout in area with adjacent IOL lands.
Source: Government of Canada, CIRNAC Website

A zoom in shows how the cell blocks project into irregular boundaries where crown mineral rights are not allowed. Clients are required to pay for the areas within cells that they are not entitled to.

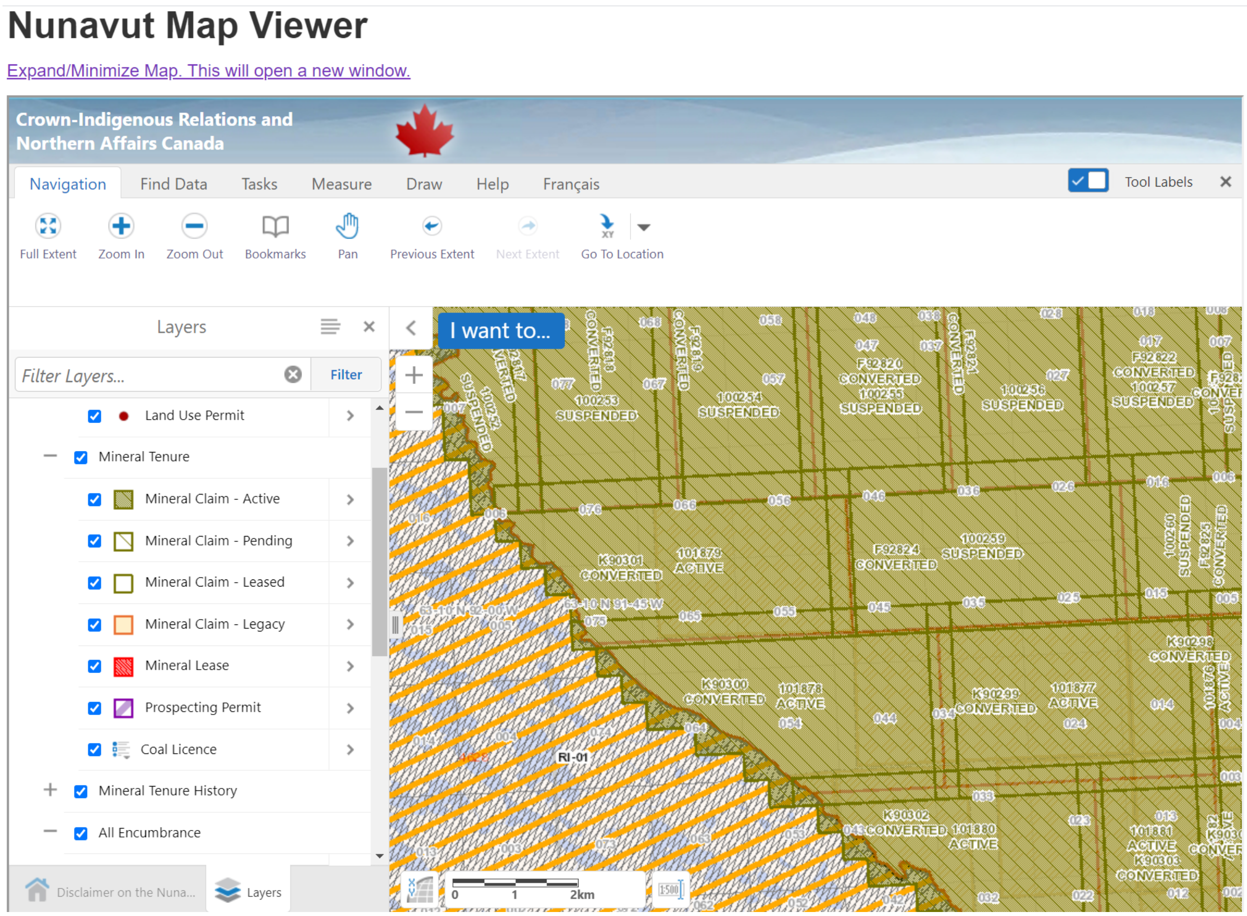

Figure 15: Zoom-in of Figure 14 showing cell overlap into IOL parcels.
Source: CERNAC Website

This is typical of grid-based systems where it is not possible to exactly match irregular boundaries.

A Nunavut official was interviewed, and two other officials provided written responses to the questions. Nunavut never considered anything other than a no-grid approach. Rationale was that "*this type of regime offers more flexibility than a regime based on map sheets*". This was confirmed by another CIRNAC official in Ottawa in that they were not aware of any options other than grid cells and tenure conversion.

As with Ontario, industry clients were consulted throughout the process and there were no disputes filed in the context of OMS implementation. Nunavut does not give clients any discount for partially owned claims (where part of the cell is in an area where mineral rights issuance is prohibited).

If NWT followed Nunavut and used the oil and gas grid, it would mean that most of Northern Canada shared a common grid albeit a creation of NRCan with possibly some loss of control. This may or may not resolve boundary issues but would still require conversion of at least 800 claims and leases.

3.2.3 British Columbia

British Columbia (BC) converted to OMS in the early 2000's and followed a voluntary conversion approach to legacy tenure. The BC cell grid, similar with Nunavut, was based on the BC oil and gas grid. The decision to build off the existing oil and gas grid avoided the need to build a stand- alone grid for minerals and allowed for easy connectivity to other government systems such as revenue collection. As with the Nunavut grid, cells project into areas where mineral rights are not allowed. BC is reliant on the underlying legislative framework to deal with this as opposed to "clipping" exactly to irregular boundaries. It is not known if there was any consideration given to not moving forward with a grid cell approach.

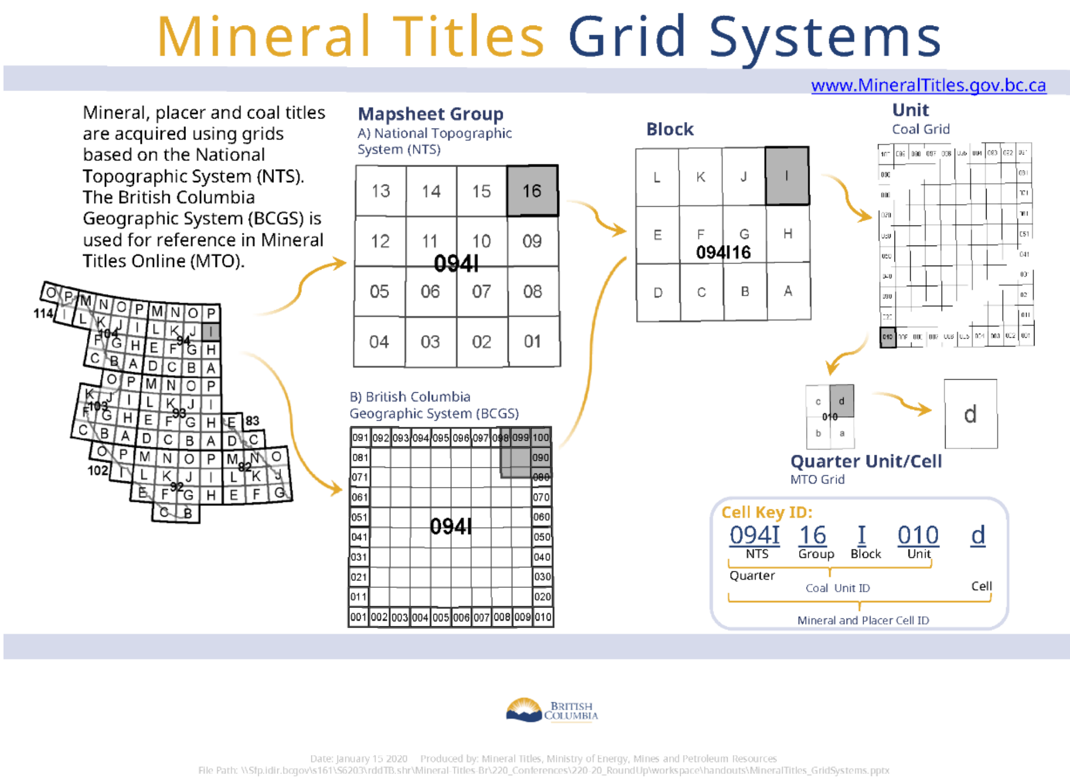

Figure 16: The British Columbia Minerals Title Grid.
Source: Government of British Columbia Website

The figure below is an image from BC Mineral Titles Online (MTO). This shows the projection of various mineral titles into a provincial park, like Nunavut, clients cannot "clip" to irregular boundaries suggesting that mineral title has been issued in the park. While the regulations clearly state this is not the case, visually it appears that tenure projects across the park boundary potentially creating issues.

As with Ontario and Nunavut, no consideration was given was given to a solution that didn't involve a grid and subsequent conversion of legacy tenure. (Although the person interviewed was not involved in early decision making). Consistency with other grids was a more important consideration. Because of the decision to move forward with voluntary conversion this process is still not complete after 15 years and results in the requirement for ongoing resources to manage conversion although the administrative process for legacy claims is like that for cell claims.

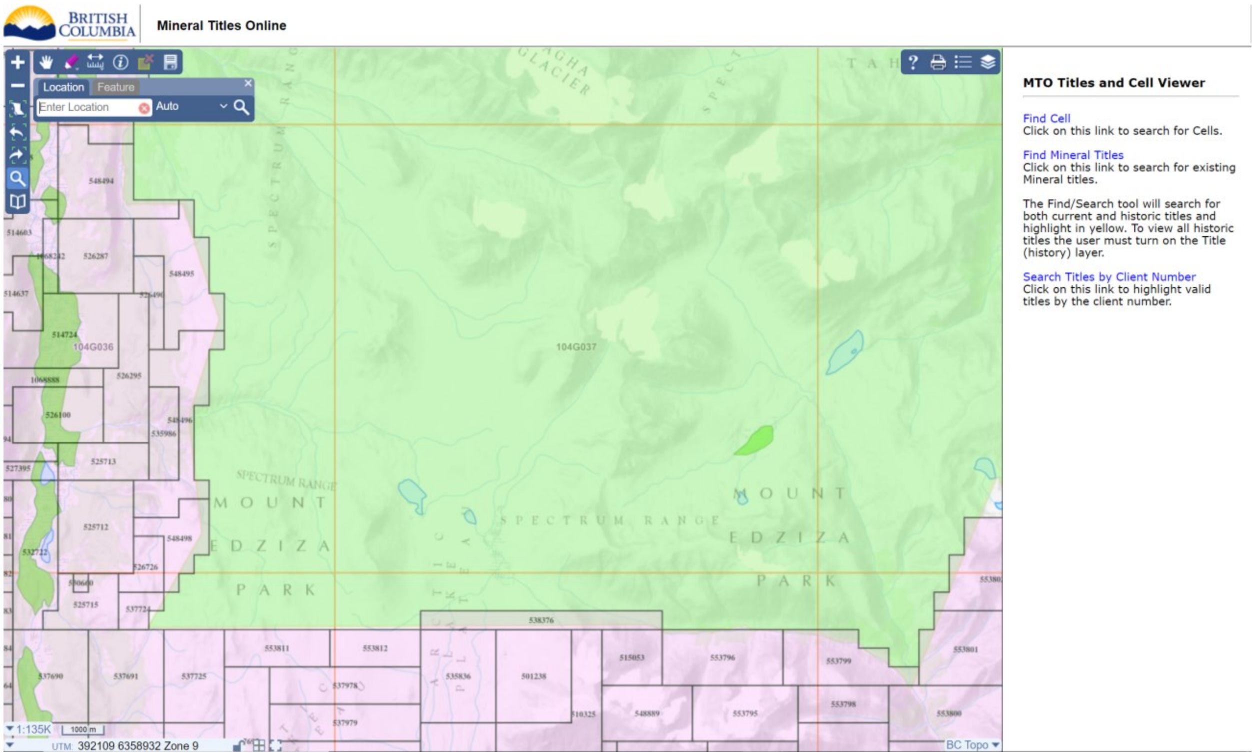

Figure 17: BC MTO showing mineral titles projecting across the boundary of a provincial park.
Source: Government of British Columbia Website

3.3 Industry Association Outreach

Various attempts have been made to connect with industry associations to determine Industry attitudes to OMS in various jurisdictions. The following organizations have been contacted:

- Ontario Prospectors Association
- Namibia Chamber of Mines
- Tanzania Chamber of Mines

None of these approaches resulted in responses; however, in the interviews and written materials received from the various jurisdictions to-date, the consensus is that industry has mostly favourably adopted the OMS approach and mineral rights acquisition in these jurisdictions increased significantly after the implementation of OMS and has remained consistently higher than before OMS (see notes from meetings/written responses in Appendix B).

3.4 Analysis

Table 3: Summary of Features of OMS From Jurisdictions Surveyed

Jurisdiction	Approach	Coordinate System	Conversion Approach	Comments
Ontario	Predefined grid cell system	Latitude – Longitude based provincial grid	Mandatory	Five-year timeframe from grid to implementation (32,000 claims)
Nunavut	Predefined grid cell system.	Northern oil and gas grid NAD 27	Mandatory	Main problem on implementation was related to security for user authentication because of the connection to the Federal Government IT infrastructure.
British Columbia	Predefined grid cell system.	National Topographic System, based on the Oil and Gas grid	Voluntary	After 15 years substantial legacy tenure remains despite incentives for conversion.
Greenland	Coordinate selection.	Latitude and longitude,	N/A	Greenland essentially kept the same approach and improved it with new technology.
Namibia	Coordinate selection or dynamic online area selection.	Latitude and longitude but based on unique projection (Bessel 1841)	N/A	Namibia is still implementing their system but does not envision moving to a grid because of cost of conversion.
Tanzania	Coordinate selection.	Latitude and Longitude	N/A	Variance from the N-S, E W orientation is allowed. All applications are reviewed and approved by minerals commission.

The jurisdictional scan shows that there is no “binary” choice between a grid cell approach and a no-grid approach, rather there is a spectrum of choices between the rigid predefined grid approach adopted by Canadian jurisdictions and a completely free form polygon approach best exemplified by Namibia. Between these two end members are approaches taken by Tanzania and Greenland where mineral rights are selected by coordinates with some rules outlined in legislation or regulation. Figure 18 below demonstrates this range of options demonstrating how free form polygons are gradually transformed to more regularized shapes and ultimately forced to conform to an underlying standardized array of grid cells.

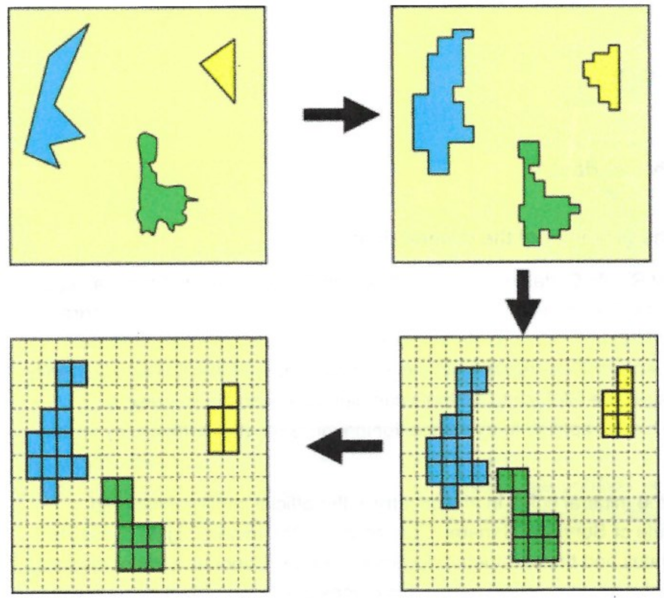

Figure 18: Transformation of free-form polygons to standardized grid.
Source: World Bank, June 2009 Mineral Rights Cadastre, p. 18

All Canadian jurisdictions have elected to implement the grid cell end member, Namibia is closest to the first box in the above diagram (as it allows non orthogonal polygon selection – see Figure 4) with Tanzania and Greenland closest to the second box preferring N-S, E-W oriented claim blocks although it is possible to apply for an exception to this to outline a free-form polygon that perhaps better matches underlying geological trends in Tanzania and the irregular coastline of Greenland. Neither Tanzania or Greenland have implemented a grid or undergone a conversion process. In both Tanzania and Greenland, it is possible to clip exactly to irregular boundaries if required because there are no pre-selected cells, although because of an incomplete technology package in Namibia, this is completed "in the back office" by Government officials. The Tanzania portal shows clipping to irregular boundaries; however, as it is possible for mineral tenure to be issued in game preserves (activities are subject to consent of managing authority), it is not always required to do this (i.e., it is a client choice).

The choice that is available to jurisdictions is the amount of freedom given to clients within the system to outline the polygons defining mineral rights. The current NWT ground-staking system approximates the second box on the above diagram (i.e., mostly roughly N-S, E-W orthogonal claims) except in the area around Yellowknife where old, irregular polygon claims are present.

All three grid- based jurisdictions investigated at have the same issues created by the rigid cell grid approach.

- Existing mineral rights must be converted to conform with the grid. Both voluntary (BC) and mandatory (Nunavut, Ontario) conversion have been used to accomplish this. The former has resulted in large amounts of legacy tenure having to be managed. Both approaches result in the need for often complex processes for conversion to ensure existing tenure holders do not "lose" rights and for boundary issues between existing tenure holders. This can be a very complex administrative process (5 years in Ontario, incomplete after 15 years in BC)

- It is difficult to prevent grid cells projecting into areas where mineral rights issuance is restricted which can create confusion when viewing tenure maps. This also applies to existing mineral rights that cannot be converted such as surveyed mineral leases. While underlying legislation is often clear on which areas prohibit mineral rights issuance, in practice this results in the need to highlight the overlap areas creating a complex and sometimes difficult to view map with various hatching schemes used to highlight overlaps. For particularly sensitive areas (e.g., international borders, private Indigenous Lands), some jurisdictions intentionally leave gaps so that no cells project across the boundary creating a sterile area.
- Unless the underlying system is designed to deal with the cell overlaps into restricted areas clients will often have to pay for the area that they are not entitled to own as is the case in Nunavut (that includes land in the NWT).

That said, once implemented, grid cell systems do create a very orderly system and since the grid cells are fixed geographically, they provide a permanent record of activity related to that area. This in contrast to more open systems (similar with the current NWT approach) where lapsed claims may be partially re-staked so that over longer periods of time it may be difficult to track back to past work records especially if document retention policies result in destruction of records after a set period. This is less of a risk given MRA proposals for increased work filing of technical work or statistical reporting.

None of the jurisdictions interviewed went through any detailed analytical process to decide between a grid and non-grid approach. Answers to this question elicited a couple of responses – technology that worked better with a grid approach (Ontario) and more flexibility than "map-sheets" (Nunavut). Further, BC, Ontario and Nunavut used Pacific Geotech to implement OMS. The Pacific Geotech website specifically states that their system is grid-based.

'More about truePERMIT

Our platform truePERMIT was designed by Pacific GeoTech Systems Ltd. (PGTS) to support mining cadasters, oil & gas registry and permitting management systems and water licensing and land assessment solutions. PGTS is a worldwide leader in delivering online enterprise resource management systems.

*truePERMIT has been implemented in many jurisdictions of all sizes including some of the major mining hubs in Canada, such as **Ontario, Manitoba and British Columbia**, and internationally in Colombia, South America. Our truePERMIT platform is the next generation (4.0) of resource management systems featuring:*

• A process driven model with configurable Business Process Management Workflows (BPMN 2.0).
• A client portal for end users.
*• Full GIS capabilities including**: online map staking option using spatial grid**, automatic land status which improves data management, and increases data integrity and transparency.*
• Full resource management capabilities including: permitting, health and safety, incidents, compliance, mobile inspection, digital signature, blockchain, AI, live feed for satellite data on demand.

Since the truePERMIT solution has been deployed in some major mining hubs, a large number of mining companies in the world are using the system, and significant global mining revenue is reported through the deployed system'

All three grid jurisdictions emphasized decreased potential for conflicts with this approach. The three non-grid jurisdictions interviewed have taken the approach of migrating their past approach to an OMS environment. None appeared interested in undertaking the effort to move to a grid system because of lack of resources and complexity (Namibia) and simply no interest (Greenland, Tanzania).

In the current NWT context, the following are key considerations:

- The NWT currently has a relatively low number of active Mineral Claims and roughly half of existing mineral rights are Mineral Leases. This would mean that the number of mineral claims required to be converted is relatively low given that Mineral Leases are not subject to conversion. In addition, many mineral rights are held by a limited number of companies (e.g., Nighthawk Gold, GoldTerra, Osisko Metals) so conversion would be made simpler. See Section 4.4, for a geospatial analysis of active tenure with shared boundaries and different neighbouring owners. Therefore, if there is a consensus that NWT should proceed with a grid- based OMS, then this would be a good time as workload associated with conversion would be relatively low although this situation could change rapidly with a staking rush which might result in an unanticipated increase in workload. The biggest issue with this approach would be working with the large number of irregular boundaries of areas where Crown mineral rights issuance is prohibited. Maps showing mineral rights projecting into National Parks or land where Indigenous Governments hold title would be problematic given the sensitivity around land management in the NWT.
- Countering the above is that moving to a grid- based OMS would require a substantial rewrite of the regulations. Because the current ground-staking rules are built around the concept of N-S, E-W oriented mineral claims migrating to an OMS that simply moves these regulatory rules to an OMS system may be relatively simple as a new grid would not have to be described in regulation. This combined with a technical geomatics approach that allows “clipping” to irregular boundaries may be a solution that minimizes regulatory drafting and impact on clients.

These issues are discussed further in the following geomatics portion of this report.

4. GEOMATICS ANALYSIS

Research was conducted to explore the various geomatics scenarios presented in the cross-jurisdictional scans in the context of the NWT. Based on this research, a geomatics related analysis was completed to define the advantages and disadvantages of the geospatial technologies implemented by each jurisdiction. Specifically, the analysis focuses on the limitations, issues, functionalities, workflows, and efficiencies within each type of system implemented. The systems can be categorized broadly into two types; grid and no-grid, as described in Section 3 above. A closer look at the types of systems implemented, completed through the jurisdictional scan, shows that there is no “binary” choice between a grid cell approach and a no-grid approach. Figure 19 below shows the spectrum of scenarios, on a scale from less rigid to more rigid, discovered in the jurisdictional scan. As can be seen, there are various ‘sub-types’ within grid and non-grid systems.

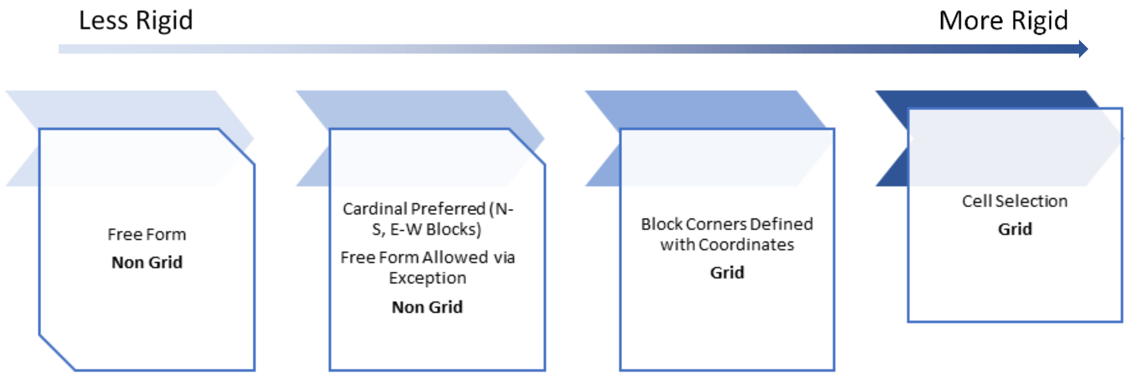

Figure 19: Example spectrum of OMS geospatial systems.

The geomatics analysis attempts to define the advantages and disadvantages of each system within their broad definitions. Specific regard is given to the sub-types where applicable in each section.

4.1 Database Limitations, Restrictions and Requirements

Web- or online- based geospatial solutions rely on Geospatial Database Management Systems (DBMS) to serve and store geospatial data such as points, lines, and polygons (features)[8]; (i.e., mineral rights boundaries). Geospatial DBMS allows for multiple users to share, edit, and access data simultaneously[8] through web-based geospatial solutions. While these systems allow for large volumes of geospatial data to be handled by multiple users they are not without limitations. The geospatial analysis conducted looked at limitations specific to the implementation types discussed above, and does not discuss limitations or allowances imposed by available technologies such as multi-threading, hardware specifications, cluster computing, bandwidth, etc. as these technologies are changing at a rapid pace and continue to improve over time. OMS systems are built on web-based geospatial software frameworks, an example of a common web-GIS framework is shown below in Figure 20.

[8] Jenna Lyons, "Geodatabase vs. Geospatial Database: What's the Difference?," Safe Software, March 3, 2021, https://www.safe.com/blog/2021/03/geodatabase-vs-geospatial-database-whats-difference/.

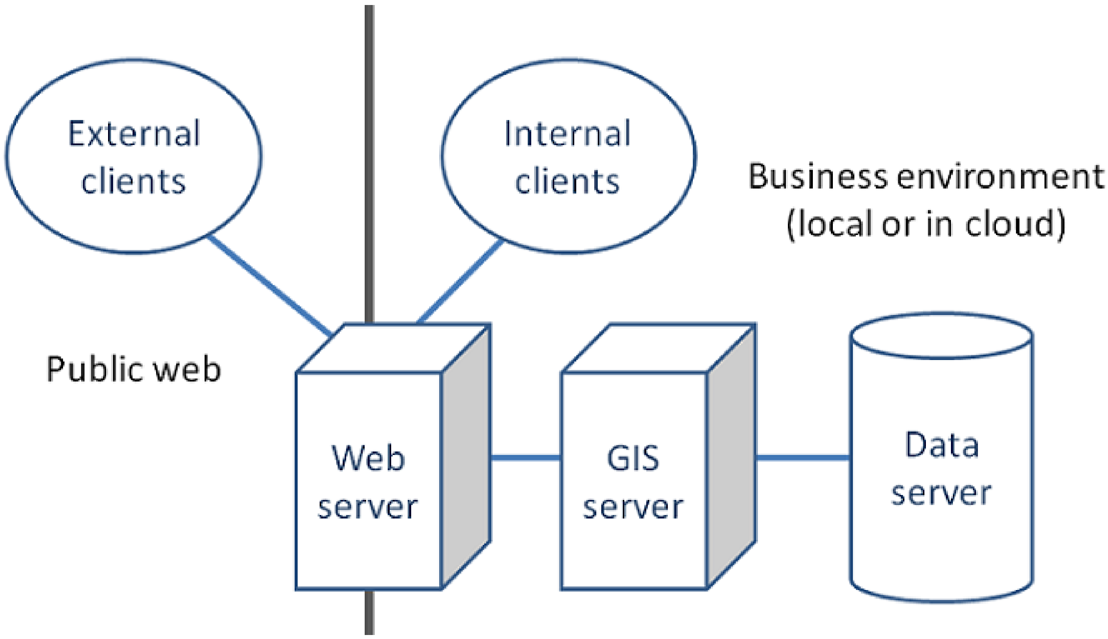

Figure 20: Example Web-GIS framework/architecture[9].

4.2 User Volume and Traffic Limitations

User volume and traffic to OMS systems can be highly dependent on several factors including, but not limited to market conditions, number of active mineral rights and obligations, seasonality, and public awareness. As of mid-August 2021, there are 2,537 active and pending mineral claims, active mineral leases, and active prospecting permits in the NWT[10]. These 2537 active mineral rights belong to 117 unique entities or joint-venture partners[10]. See Table 4, Table 5, and Table 6 below for a detailed summary of mineral rights status.

Table 4: Mineral Claim Status Summary[10]

Claim Status	Number of Claims	Total Area (Ha)
Active	1,191	752,405.35
Cancelled	20,260	16,662,013.15
Leased	1,048	837,786.53
Pending	5	5,850.00
Refused	68	33,090.02
Withdrawn	108	85,966.48

Table 5: Mineral Lease Status Summary[10]

Lease Status	Number of Leases	Total Area (Ha)
Active	1320	894,719.255
Cancelled	354	218,307.28

[9] Central Washington University and Sterling Quinn, "Web GIS," *Geographic Information Science & Technology Body of Knowledge* 2018, no. Q1 (January 1, 2018), https://doi.org/10.22224/gistbok/2018.1.11.
[10] NWT Centre for Geomatics, "All Mineral Tenure," Dataset (Government of Northwest Territories), accessed August 22, 2021, https://www.geomatics.gov.nt.ca/en/mineral-tenure-all-0.

Withdrawn	2	1,858.46

Table 6: Prospecting Permit Status Summary[10]

Prospecting Permit Status	Number of Prospecting Permits	Total Area (Ha)
Active	21	330,728.77
Cancelled	532	9,101,504.86
Withdrawn	639	10,642,796.89

The capacity for a web-GIS framework, such as an OMS system, to handle user volume or traffic relies on the underlying software and hardware capabilities[9]. Grid and no-grid-based implementations of OMS systems do not appear to incur any user volume or traffic limitations particular to the implementation types.

The user on-boarding, or initialization process (account setup) is the first step in providing access to the end user. A large volume of account setup requests may occur at the deployment of a new OMS system, as seen in Nunavut[11]. Nunavut's implementation of user on-boarding was noted as a limitation of the system, experiencing delays of up to a week or more in account setup. These delays were attributed to the integration between the OMS system and the Federal Information Technology (IT) systems. End users of the Nunavut system are utilizing the Federal Government's authentication system to login.

Ontario also noted a large volume of user traffic in the first weeks of implementing an OMS system, describing it as a 'massive staking rush', and experienced higher levels of mineral rights activity that have since been maintained.

4.3 Required Administrative Capacity

Differences in the required administrative capacity for each implementation type are linked mainly to the conversion process of legacy tenure into a new system. There are additional administrative requirements in implementing a grid-based OMS system related to the joining of selected grid cells with restricted or prohibited areas per jurisdiction (i.e., protected areas, existing surface/subsurface rights, and alienated areas).

No-Grid Implementation

In a no-grid system, the conversion of legacy tenure to an OMS system requires less effort to migrate existing mineral rights relative to a grid system[2]. The conversion process of legacy tenure in a non-grid implementation generally does not require a change to the legal size and shape of the tenure, thus requiring less effort from the administrative team in migrating to a new system. Greenland noted this specifically, in migrating from a coordinate-based record management system of mineral rights to an OMS system, no issues were encountered for the administrative team of four.

Grid Implementation

The administrative capacity required for a grid-based OMS system database is much greater than that required of a no-grid system[2]. The largest requirement for administrative capacity is linked to the

[11] Tracie McCaie, Jurisdictional Scan - Questions for Grid Jurisdictions, Questionnaire, August 20, 2021.

conversion of legacy tenure into a cadastral grid; although there are multiple methods of converting legacy tenure into a grid system[2] each would require numerous changes to existing NWT regulations. Ontario provided its end users with a staking hiatus or "pre-conversion period"[12] of three months to allow existing rights holders convert claims to the new system and agree to or dispute the newly defined extents of tenure based on the grid cells. After the pre-conversion period, the newly defined mineral claims became defined in legislation by where they exist in the OMS system, preventing further opportunities for dispute.

4.4 Geospatial Record Management Limitations and Issues

Geospatial DBMS and the web-based geospatial solutions that are built upon them are primarily limited by underlying hardware and software capabilities[9]. Performance improving techniques exist in web-based geospatial solutions[13] although these are highly specific to the software and technologies employed, not directly related to the implementation types being discussed. Both no-grid and grid implementations will experience the benefits of raster and vector tiling in a web-based geospatial solution[14]. Research did not discover editable vector tile layer implementations; at this time the performance benefits of vector and raster tiling is limited to background or base map data that does not require layer symbology or feature edits.

No-Grid Implementation

A no-grid implementation or free form approach to OMS potentially allows an end user to digitize and apply for mineral rights with many feature vertices defining their extents. A greater number of feature vertices can have a negative effect on the performance of a web-based geospatial solution[15]. Both Tanzania and Greenland have implemented a more hybrid approach to a no-grid implementation. In both countries, a N-S and E-W orientated boundaries are preferred, while allowing for exceptions to these guidelines through an application process to the respective MROs. Following this method greatly reduces the number of coordinates or vertices required to define the extents of common mineral rights, while allowing for edge cases, i.e., adjoining to irregular boundaries (e.g., land withdrawals), following an underlying geological trend, etc. Depending on the software or technology implemented, this variant application process may require further administrative capacity, though it is possible that an automated solution or workflow may exist.

Grid Implementation

A grid implementation requires the generalization of legacy mineral rights, and the selection of new mineral rights conform to a cell-based cadastre system. While this type of OMS system may appear to simplify or generalize mineral rights, depending on the jurisdictions existing tenure, it may create more complexity than a free form or no-grid implementation[2]. The figures below, extracted from a 2017 Trimble

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[12] "Mining Act," Ontario Regulation 455/17 Transition - Electronic Registration of Mining Claims § Definitions (2017).
[13] Chaowei (Phil) Yang et al., "Performance-improving Techniques in Web-based GIS," *International Journal of Geographical Information Science* 19, no. 3 (March 2005): 319–42, https://doi.org/10.1080/13658810412331280202.
[14] Sterling Quinn and John A. Dutton, "Why Tiled Maps?" (College of Earth and Mineral Sciences, The Pennsylvania State University), accessed August 22, 2021, https://www.e-education.psu.edu/geog585/node/706.
[15] Micah Babinski, "Tips and Tricks to Supercharge Your Web GIS," *ArcUser*, Fall 2016.

Whitepaper[2] depict an example of the added complexity of converting legacy tenure to a grid implementation, notably affected by a mix of large- and small- scale legacy tenure – in the context of the NWT the examples shown could be viewed as prospecting permits (large scale) and mineral claims or leases (small scale).

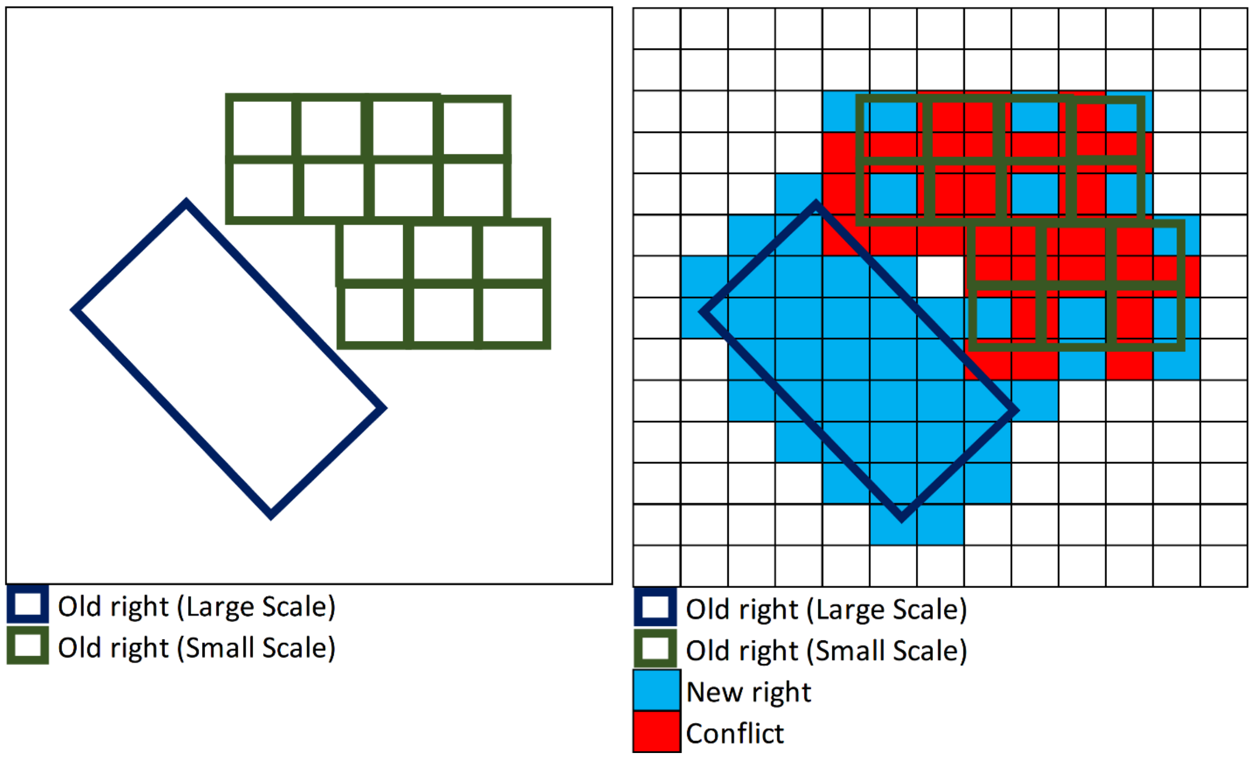

Figure 21: Example legacy rights and conflict generated in conversion of legacy rights to grid cells [2].

As can be seen above, not only can the conversion of legacy rights to a grid or cell system create complexities and conflicts between existing mineral rights, but it can also increase the complexity of the feature extents representing the rights or tenure. In this example, the large-scale legacy right was originally defined by four points or coordinates, after conversion it is defined by 160 points and 40 cells. The level of complexity added is greatly affected by the cell or unit size chosen for the grid implementation[2], as discussed above, the addition of vertices can have an affect on the performance of web-based geospatial solutions like an OMS system. As an example, the NWT Oil and Gas Grid was examined using GIS and the combined total of all vertices representing land based grid cells is 908,152 points. To put this in context, with modern geospatial relational database management systems, a very popular open-source example, PostGIS, was looked at. PostGIS can store a single geometry with a theoretical limit of 67,108,864 vertices, using approximately 1 GB of storage and a proven limit of 33.5 million vertices[16]. Provided that PostGIS is capable of storing multiple geometries at these limits, it becomes apparent that the limiting factors on storage and bandwidth are hardware based, and to a less extent limited by the software technologies of today.

[16] Dan Baston. "What Is the Maximum Size of a PostGIS Geometry?" Blog. Danbaston.Com (blog), November 28, 2016. http://www.danbaston.com/posts/2016/11/28/what-is-the-maximum-size-of-a-postgis-geometry.html.

A geospatial analysis was conducted to determine the number of active mineral claims and leases that share boundaries with or are neighbouring other active tenure. There are 781 mineral rights that are neighbouring one or more mineral rights with one or more different owner(s). This represents approximately 31% of the total active tenure. On average, these rights have 2.44 neighbouring rights from different owners, to upwards of 10 rights sharing the boundary of another right. An example of the complexity found in the mineral rights fabric of the NWT can be seen in Figure 22 below. The geospatial analysis did not consider rights that were within a specified distance of one another, but do not share a boundary. Although further analyses could be conducted to examine these scenarios, based on a specified grid or cell size.

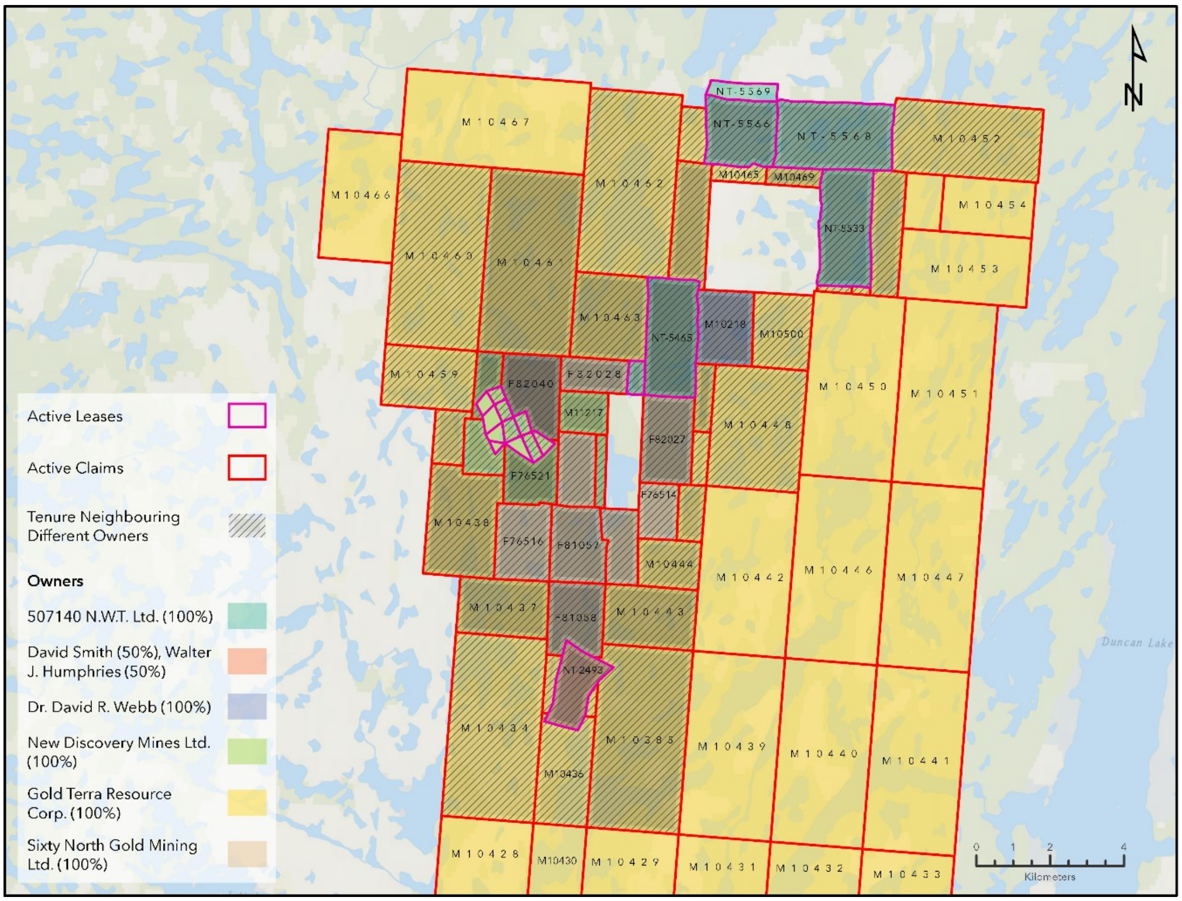

Figure 22: Example active mineral leases and claims in the NWT with shared boundaries.
Source: GNWT Website

4.5 Web Based Functionality, Data Validation Workflows, and Related Administration

Thorough testing of the various jurisdictions web-based geospatial systems was not possible during the research performed, as such data validation methods in the application for, and administration of, rights or tenure was not examined in a production environment. Both the grid and non-grid jurisdictions reviewed implemented some form of front-end or client-side data validation as well as a back-office (back end) data validation. Greenland, for instance, has implemented a front-end system that automatically prevents end users from applying for rights in restricted and protected areas. Similarly, the Ontario system does not allow the end user to select a cell that overlaps a restricted or protected area. In both scenarios, applications can be made to apply for the area surrounding the regulated areas, see Figure 23 below.

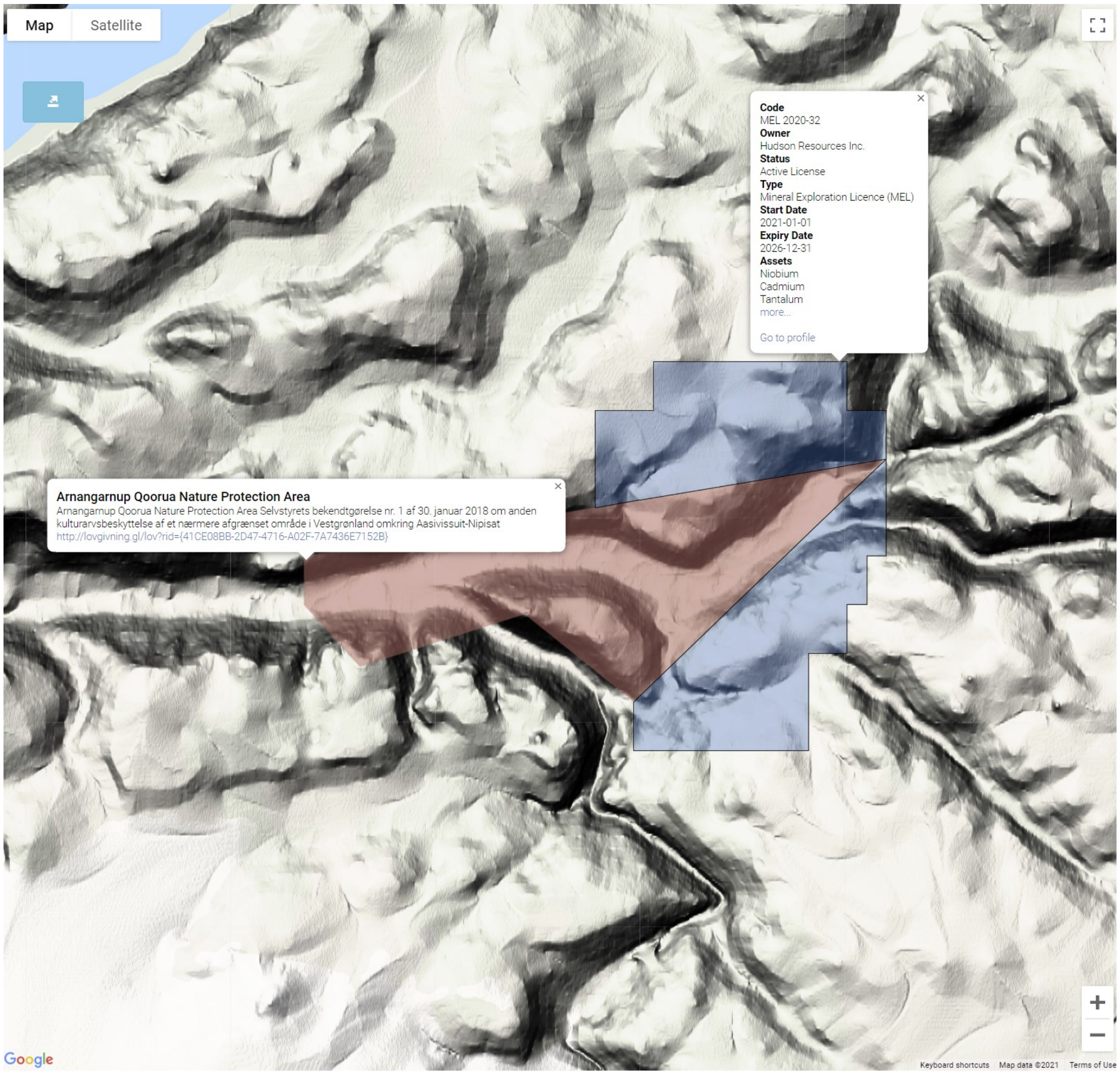

Figure 23: Example mineral right, in Greenland, adjoining a protected area.
Source: Greenland Online Applications Portal Map

A difference being, the grid system implemented by Ontario requires payments and assessment for the entire unit or cell area, regardless of the size of the unregulated area – the same is true for Nunavut. Whereas the Greenland non-grid implementation only requires assessment or payments for the area staked.

<u>No-grid Implementation</u>

Many modern web-based geospatial solutions have built in advanced editing capabilities such as snapping and auto-closing polygons[17]. These features allow users, both on the client side and back-office side, to

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[17] Alexey Noskov and Alexander Zipf, "Back End and Front End Strategies for Deployment of WebGIS Services," in *Sixth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2018)*, ed. Kyriacos

complete workflows with higher efficiency and accuracy. Until relatively recently, these advanced editing capabilities did not exist in web-based geospatial solutions; this may have prevented some jurisdictions from choosing a non-grid implementation during the production of an OMS system.

Grid Implementation

Data validation for a grid implementation is relatively straightforward - following the complexities of legacy rights conversion, discussed Grid Implementation above - consisting of a rigid or fixed set of cells, a grid system, requires the end user to select one or more cells or units to apply for rights within. The rigidness of this type of system lends itself well to older web-based geospatial solutions, preventing possible digitization errors that may have occurred without the advanced editing and data validation capabilities available presently.

4.6 Adaptability of Geospatial Solutions

Non-grid and grid implementations of OMS systems require flexibility and adaptability to changes in technology, regulations, and standards. Some issues related to the adaptability of geospatial solutions are generic to both grid and non-grid implementations. For example, software application updates are required to prevent security vulnerabilities, fix issues or bugs in software, and enhance performance and functionality[18]. BC has shown that it is possible to maintain software, as was noted, the software in production is almost 20 years old. Many of the OMS systems examined in research are built upon enterprise geospatial solutions, such as ArcGIS Online and ArcGIS Enterprise, Geocortex, or Trimble Landfolio, which have pre-defined release schedules or product lifecycles. These release schedules remove organizational impediments, allowing agencies to plan in advance of software application updates.

In addition to changes in software and technology, changes in coordinate and reference systems may also occur, which can have a large impact on OMS systems. While not examined as part of the jurisdictional scan, the Government of Western Australia provides a good example of this. Since the year 2000, Australia has moved approximately 1.8 metres north-east, forcing the upgrade to a more accurate geocentric datum[19]. This upgrade has resulted in the need for changes to legislation before rights and tenure can be administered in the new datum. Similar changes to coordinate systems and datums have occurred in Canada and the NWT[20], newer coordinate systems continue to evolve and become more accurate[21], demanding OMS systems have the flexibility to adopt new datums.

[18] McAfee, LLC, "Why Software Updates Are So Important," September 19, 2017, https://www.mcafee.com/blogs/consumer/consumer-threat-reports/software-updates-important/.

[19] Department of Mines, Industry Regulation and Safety, Government of Western Australia, "Geocentric Datum of Australia Upgrade - GDA 94 - GDA2020," accessed August 22, 2021, https://www.dmp.wa.gov.au/Minerals/Geocentric-Datum-of-Australia-24738.aspx.

[20] Natural Resources Canada, "About the Canadian Spatial Reference System," April 9, 2021, https://www.nrcan.gc.ca/maps-tools-and-publications/tools/geodetic-reference-systems/canadian-spatial-reference-system-csrs/9052.

[21] Canada and Natural Resources Canada, *Mind the Gap!: A New Positioning Reference, NATRF2022.*, 2020, http://publications.gc.ca/collections/collection_2021/rncan-nrcan/M4-199-2020-eng.pdf.

Future changes to regulations are also important to consider in the implementation of an OMS system. Many web-based geospatial solutions are highly configurable and customizable[22]. Although legislation and regulations do not change quickly, there is still a need for an OMS system to be configurable to changes that may occur, preventing the need for new software development or changes to the underlying software source code.

5. RECOMMENDATIONS AND CONCLUSIONS

5.1 Geomatics

Based on the geomatics research and analysis conducted, the following section consists of recommendations in implementing an OMS system from a technological perspective. The implementation of an OMS system can be heavily reliant on administrative capacity and resources available to the government, as expressed by multiple respondents in the jurisdictional scan. Greenland merited the success of their OMS system to the simplification of the user-facing system. The simplification of the user-facing system allowed both internal government staff and external end users to easily interact with and complete transactions on the OMS system. This simplification also allowed for clearer communication of training materials to staff and end users. Similarly, the Government of Nunavut expressed that in hindsight a simpler solution to the user login and on-boarding process implemented would have been preferred. The login solution Nunavut has implemented links to the Federal Government's internal authentication system, which has several security requirements and complexities, causing delays and administrative demands on staff.

The delays in user on-boarding at the outset or deployment of the Nunavut OMS were exacerbated by an initial surge in traffic, causing the process to take up to a month to complete. This surge in traffic during deployment was also experienced by Ontario as discussed above. Both Nunavut and Ontario implemented a 90-day transitional[23] or pre-conversion period[12], potentially increasing the early demand on the new system. This 90-day period was required to convert legacy tenure to a grid-based implementation, due to the change in legal description of existing mineral rights. The initial surge in traffic and high-demand on the web-GIS solution implemented may be mitigated by implementing a non-grid OMS system, as a staking hiatus would not necessarily be required, alleviating the potential for built up demand. While initial demand may be difficult to quantify for either grid or no-grid implementation, it may be possible to estimate user volume or traffic based on forecasted exploration funding and industry activity alongside existing numbers of mineral rights and rights holders in the NWT. Matching these estimates with hardware and software specifications required to sustain the web-GIS framework supporting an OMS system is advised.

Performance of an implemented OMS system can be measured by responsiveness and speed with which operations are performed, while it is also important to consider efficiencies that can be achieved through the automation of workflow processes. BC's MTO is about 20 years old, and BC officials expressed issues

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[22] ESRI Inc., "ArcGIS Enterprise," accessed August 22, 2021, https://www.esri.com/en-us/arcgis/products/arcgis-enterprise/overview; "Geocortex," accessed August 22, 2021, https://www.geocortex.com/; Trimble Land Administration, "Land Management," accessed August 22, 2021, https://landadmin.trimble.com/solutions/land-management/.

[23] Crown-Indigenous Relations and Northern Affairs Canada, "The Amended Nunavut Mining Regulations (2020) 90-Day Transitional Period," accessed August 22, 2021, rcaanc-cirnac.gc.ca/eng/1516209048335/1547751206407.

faced in trying to develop automation for processes that are otherwise completed manually. The automation of workflow processes implemented within the OMS system were recommended by the BC Government to reduce the administrative capacity required in manually completing these tasks.

Technological advances in web-GIS software and the underlying hardware systems on which they run continue. Implementing an OMS solution that matches the requirements of current and future exploration demands with modern technologies in the context of the NWT and its regulations will be imperative to the success of the industry.

5.2 Industry/Client Perspective

The grid system conversion creates the opportunity for dispute of new cell-based claims.

Licensees only stake what they want in Greenland. This is an advantage for industry as they only pay for what is staked.

It is strongly recommended that ITI consult with existing and potential clients to determine what their perspective is with regard to a grid versus no-grid approach or a combination thereof.

5.3 General Conclusions

Research on jurisdictions that have implemented (or partially implemented) OMS shows that the majority have implemented some sort of grid cell selection approach. Extensive research and detailed follow up interviews with 6 jurisdictions suggest that the reason for the preference towards the grid cell approach may be based on the following.

- Technology limitations and/or limited availability of vendors that tended to favour a grid approach (see Ontario) particularly until the early 2010's.
- A body of work produced by the World Bank and other UN institutions in the mid to late 2000's that promoted the grid cell approach as best practice as numerous jurisdictions moved to adopt OMS.
- A herd mentality as jurisdictions strove for competitiveness and as such tended to move in the same direction as early adopters.

Only a few jurisdictions chose not to implement grids and essentially migrated their pre-OMS tenure selection towards a more client friendly OMS environment without converting existing tenure to rigid grid cells. In the six interviews conducted, it was apparent that none undertook a detailed analysis of the advantages and disadvantages of grid vs no-grid approaches instead basing their decisions on the above factors or simply resource availability/lack of perceived need for a grid although the costs and complexities of conversion of existing tenure to a grid was a major factor for Namibia.

Of the six jurisdictions interviewed, BC was an early implementor and likely had little options in terms of available technology. However, by the mid 2010's technology suppliers such as Trimble were questioning the need for jurisdictions to implement grid- based systems based on availability of much improved geo-spatial technology. In particular, the World Bank reports promoting the grid cell approach were questioned in a series of papers in 2017 and 2018. Considering that Trimble implemented (and still does), the grid cell approach, this was not based on promotion of proprietary technology. Rather it was based on observations that jurisdictions used significant resources on conversion of legacy tenure when the focus maybe should have been on other issues.

“It is our experience from working in numerous countries that the process of implementing a cadastral grid has typically distracted the Regulatory Authority from conducting their mission critical and mandated responsibilities” (Trimble White Paper, 2017)

Table 5 below summarizes the main advantages and disadvantages of grid vs no-grid approaches to OMS based on the research and interviews

Table 5: Summary of Advantages and Disadvantages of OMS Approaches

Approach	Advantages	Disadvantages
Grid	Minimizes chance of future conflict. Fixes absolutely the location of a claim. Cells remain fixed forever, so anything recorded against a cell is permanently preserved. Creates a very orderly arrangement of mineral title.	Requires up front decision on grid coordinates, cell sizes. Not reversible without extreme cost. Requires conversion of legacy tenure, creation of various rules around existing tenure where multiple legacy claims intersect a single cell. Inflexible on irregular boundaries- cells project into areas where issuance of mineral rights is prohibited again requiring creation of rules around what portion of costs of the partial cell clients must pay (100% in Nunavut, 50% in Ontario). Requirement for large amounts of training both for staff and clients.
No-grid	No requirement for conversion of legacy tenure results in quicker implementation, less resources. The system will look familiar to clients especially if business rules for shape/size/orientation of claims are like existing ones for ground staking. Irregular boundaries are respected with no cell projection or requirement for sterile areas adjacent to borders etc. Business could be changed without the need to change an underlying arrangement of cells.	Appears to be going against consensus favouring grid approach in Canada and Internationally. Possibly more potential for conflict depending on coordinate system and ease of use for clients. Appearance of cluttered tenure depending on number of vertices allowed to define tenure.

The main conclusion of the research is that as opposed to spending too much time researching the two approaches, the main policy objectives of migrating to OMS need to be defined and then an approach selected based on the advantages and disadvantages listed above. Given that other than the Yellowknife area most mineral rights are N-S, E-W oriented it may be that an approach to OMS favouring this orientation be adopted as that would simplify future “clipping” of new mineral rights to surveyed mineral leases. This would also simplify regulation drafting if claims were maintained at roughly the current size. An allowance could be built in allowing for non- N-S, E-W orientation shapes on application as in Tanzania if this would result in lower vertices. This would see the NWT move to an approach similar with that of Tanzania.

There are several conclusions and recommendations specific to geomatic considerations that will need to be considered once a decision on approach has been made.

5.4 Geomatics Conclusions and Recommendations

In completing the research, several conclusions pertinent to geomatics are apparent regarding either a grid or non-grid approach or both. The relevant conclusions and recommendations will need to be considered once a decision on approach has been made.

Table 6: Geomatics Conclusions for OMS Systems

Grid	Both	No-grid
The conversion of legacy tenure to a grid implementation generally requires a pre-conversion period or time during which no applications for mineral rights may be made. This could be seen to reduce exploration activity and investment during this time The complexity of tenure converted to a grid implementation is highly related to the cell or unit size chosen for the grid. A larger grid size will reduce the complexity of the grid but will result in the loss of definition between the underlying geology and bounding mineral rights. Conversely, a smaller grid cell or unit size will increase the complexity of the mineral rights fabric, and allow for finer definition of mineral rights	The implementation or deployment of an OMS system appears to coincide with a greater than normal volume of applications for mineral rights. Performance improving techniques exist in web-based geospatial solutions although these are highly specific to the software and technologies employed. Data validation tools reduce the need for administrative capacity, preventing erroneous or invalid applications for rights in an OMS system. The data validation tools available are highly specific to the technologies and implementation of an OMS system OMS systems built upon enterprise grade software solutions appear to have relative longevity in the market. Pre-defined software release schedules or product lifecycles aid in planning and remove organizational impediments	From a geomatics perspective, the conversion process for legacy tenure in a non-grid system requires less work, as existing tenure can be represented in an OMS system without the need for change to the legal size and shape of the tenure A non-grid or free form approach to OMS may allow the end user to digitize and create complex non-orthogonal polygons or features. The additional feature vertices required to define the extents of these polygons may require additional system resources at scale. This could be avoided by limiting number of vertices

Geomatics Recommendations

The OMS solution chosen should be designed to handle greater than normal volume of requests. Ideally administrative processes, such as account creation, should be automated as much as possible to reduce the need for administrative capacity and the possibilities for delays experienced by the end users.

The conversion of legacy tenure to a new OMS system is far simpler when converting to a no-grid implementation, when compared to a rigid grid implementation.

If a grid approach is taken, time and substantial administrative capacity will be required to convert legacy tenure into the new cadastral grid. Regulations may be required to allow for a 'staking hiatus' during which time the conversion would occur.

Regardless of the implementation chosen (grid or no-grid), a modern solution built on recent technology will gain the performance benefits that exist today.

Limitations on the number of feature vertices, requirements for N-S, E-W orthogonal polygons, or similar validation constraints may alleviate the need for greater system resources, and reduce the complexity of the mineral rights fabric, while allowing for mineral rights that are more suitable to the underlying geology or surrounding land-use constraints.

For a grid implementation, care should be taken in choosing a grid cell size, as the complexity of the OMS system and its abilities to provide equitable mineral rights are greatly impacted.

Data validation should be implemented in both the front-end (client-side) as well as the back-office (back-end) of an OMS solution. The automation of data quality assurance and control provided by data validation greatly reduces the need for administrative capacity.