Introduction

- 2016 was the seventeenth year for our community-based project.
- Our purpose has been to accelerate the re-vegetation of barren areas in and around our communities by the application of crushed limestone.
- Because of the ruggedness of our terrain, it has not been feasible to do the work by machine, so we have used people-power, namely students from local schools and adult volunteers.
- The cooler than normal summer was also unusually wet – leading to high and fluctuating lake levels. A phenomenal blueberry season. An unprecedented fall of wet snow in early October did significant damage to trees in the bush. Mild conditions led to an almost complete melt-off by early November – and more high lake levels. Minor and infrequent snowfalls through December left us with no more than 10 centimetres of snow on the ground at year end.
- The organizational and scientific backgrounds to our project are explained in Appendices 1 and 2.

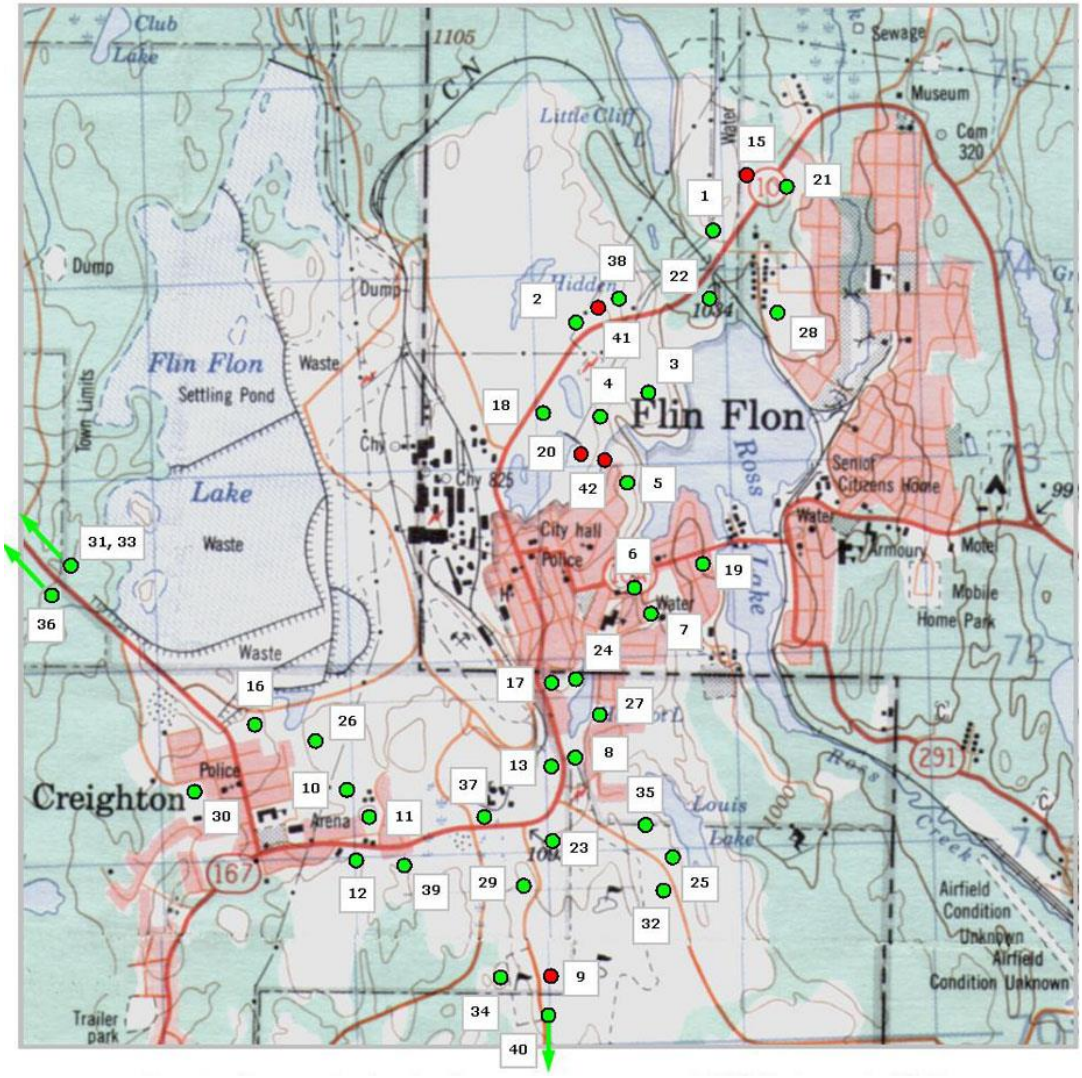
Our Partners

We gratefully acknowledge that our project has been made possible through the generosity of our partners. Funding for the work in 2016 came from Hudbay Minerals Inc. (HMI). Flin Flon School Division and its Youth Mentor program and Creighton School Division supplied the bulk of our workforce. The school divisions also provided some of the student transportation. Thanks to Edgar and Mary Wright and Donna Lundquist for help with plant identification.

Areas Treated

In the map below, green circles indicate areas we treated in 2000 through 2015, red circles indicate those treated in 2016.

Area names are as follows: 1: Balsam, 2: Rock Cut, 3: Second Valley North, 4: Second Valley West, 5: First Avenue, 6: Hiawatha, 7: Grandview, 8: Hapnot, 9: Phantom, 10: Knight North, 11: Knight, 12: Pizza, 13: South Main, 15: Esso, 16: Creighton North, 17: Super K, 18: Triple Seven, 19: Market, 20: Reservoir Hill, 21: Lancaster, 22: Railroad, 23: Phantom North, 24: Hapnot North, 25: Louis, 26: Creighton East, 27: South Hudson, 28: Roche, 29: Phantom Northwest, 30: Red Mountain, 31: Hilary, 32: Golf, 33: Sand Bar, 34: Driving Range, 35: Icehouse, 36: Creighton Creek, 37: Headframe, 38: Rock Cut North, 39: Larson, 40: Soccer, 41: Rock Cut Middle, 42: Linda.



During a field season lasting from May 31 through August 3, we spread 29.2 yards of crushed limestone (dolostone) in five areas to cover a total of 1.6 hectares (3.8 acres). During the project period 2000-2016, we have treated 59.2 hectares (146.2 acres) with 1,266.4 yards of limestone (an application rate of 21.41 yards/hectare).

Volunteer Field Personnel

The work was carried out by 495 individuals during 20 sessions. This number includes 483 Flin Flon and Creighton school students in 19 sessions in May and June. One session was handled by a group of 12 participants in the City of Flin Flon Recreation Department's 'Summer in the Parks' program in August. Details on personnel distribution are summarized in Appendix 3. At left below are McIsaac kindergartners at the Phantom area, and at right are McIsaac grade 2s at the Rock Cut Middle area.

New Growth in Treated Areas

The areas we are treating are either totally barren, or have a few scattered tufts of the acid- and metal-tolerant grass Agrostis stolonifera, and a few stunted relict poplars, birches, and willows. Original organic topsoil is commonly entirely absent, or where present is thin. The ground surface is a combination of bare rock outcrop, and sandy or silty gravel with a variable content of pebbles and boulders. Areas treated in May and early June of each project year have generally shown some signs of life (typically Manitoba maple) within a month. By August, seedlings of birch, aspen, balsam poplar, and a variety of willows appear. Although the maples tend not to over-winter well, the other species flourish, and in the second season grow to about half a metre. Conifer seedlings tend not to appear until a year or two after the treatment.

As of fall 2016, deciduous trees were more than 2 metres high in 35 of our 41 treated areas, 4 or more metres high in 26 areas, 5 or more metres high in 12 areas, and 6 metres high in 9 areas (Creighton East, Hapnot, Pizza, Knight, Knight North, South Main, South Hudson, Esso and Phantom North). Our tallest self-seeded conifers are at the Hapnot, Phantom, Pizza, Knight and Knight North areas. The tallest jack pines – commonly associated with old relict parents – are 4-5 metres high, while spruce are in the 3-4 metre range. Cones have generally been noted on pines within a few years of germination. They take much longer to appear on spruce – this season cones were noted on white and/or black spruce in six of our areas.

Until 2009, self-seeded tamarack (three individuals) had been noted only at our Knight area - the tallest is now 3.7 metres high. Since then, a few individual tamaracks have been noted at our Creighton East and Pizza areas – these are coming along nicely and are now up to a little over 2 metres high. This year, small tamarack seedlings were noted for the first time at the Soccer and Larson areas. Individual Scots pines were noted for the first time at the Knight and Knight North areas in 2010 – another was noted in the Creighton East area in 2013. These were presumably seeded from imported trees planted in local yards. The individuals at the Knight North and Knight areas are now 4-5 metres high. Alders were not seen in any of our areas until 2005 – they have now been noted in 20 - and are particularly numerous at the Sand Bar area. In five of these areas, it appears that the seed was derived from individual alders put in at our 'plantations' in 2001 – see 'Planting and Seeding' below. Individuals and small clusters of dwarf birch are present at our Knight, Phantom, Creighton East and Sand Bar areas.

Although understory species such as fireweed, rough cinquefoil, raspberry and bearberry are quite widespread, they tend in general to be few and far between. Until a few years back, our best areas in terms of variety and density of understory species had been South Hudson and Roche. In 2013 it was noted that an even greater variety and density of these species had become established at the Headframe area. The seed for these was clearly derived from immediately adjacent areas that had been landscaped by HMI a few years previously. It is of interest to note that there is a greater variety and number of understory species coming through in areas we treated at our Louis and Esso areas in 2010 than in adjoining areas that were treated in earlier years. The grass A. stolonifera tends to spread following treatment, and a few other grass and sedge species have appeared in some areas. Some of our best areas in terms of density of woody species – such as Creighton North - still have almost no understory vegetation.

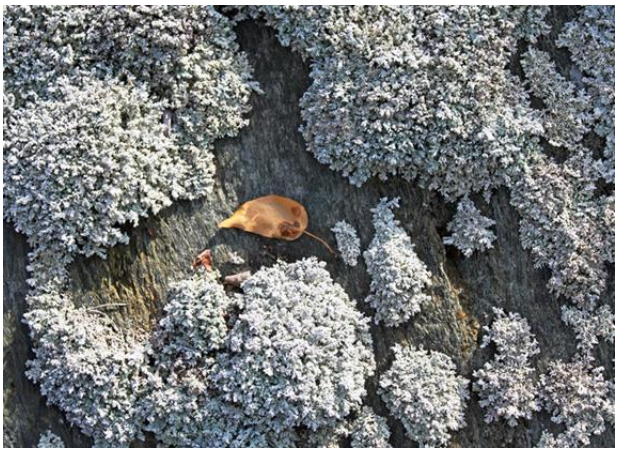
The pictures below show the very sharp lines of demarcation between areas that have received the limestone treatment and those that have not. The Phantom area at left with a dense growth of dominant birch, was treated in 2002. The Pizza area at right was treated in 2001. There has been no tendency for areas that have become vegetated following treatment to extend into adjoining untreated areas.

For the past several years, carpets of dead leaves and other forest litter have been accumulating in some of our most densely vegetated areas. These constitute the beginnings of a new organic topsoil. The mushroom Amanita muscaria was first noted in one of these shady and leaf-carpeted spots at our Knight North area in 2010. Since then, Amanita has been noted in similar situations in up to eight of our areas. Our only other mushroom, the red-brown Laccaria laccata, is very common and has been noted at most of our areas since the early days.

We have recognized since the early years of the project that some areas are 'slower' than others, that is, there is a variation in the rate of germination, growth and in vegetation density from one area to another. We hope that studies presently underway – see 'Scientific Studies' below - will provide an explanation and a remedy for this. The map - appendix 4 - provides an indication as to how well each individual area is progressing. Parameters used in constructing the map are: density of woody species, height of woody species, number of under-story species present, and presence or absence of self-seeded conifers. It is notable that the four areas characterized as 'poorest' are within about a kilometer of the HMI stack. The six areas characterized as 'best', are all south and southwest from Flin Flon.

There is little sign of any natural recovery of vegetation in smelter-impacted areas that remain untreated in the immediate Flin Flon and Creighton areas, however a recent

Manitoba Geological Survey report (GR2014-1) indicates that some recovery is apparent in more outlying areas. Author E. C. Syme notes that in the Lake Athapapuskow area some 10-30 kilometres southeast from the HMI stack, on rock outcrops that were clean when he mapped them during the summer field seasons 1985-1989 – "lichen has vigorously re-established itself … in more recent years, resulting in a much diminished quality of exposure." Something similar may be starting to happen much closer to Green Project areas – the pictures below were taken in August this year on a rock outcrop in the old gravel pit adjacent to the highway 10/10a junction.



Planting and Seeding

Although we depend primarily on the natural 'seed rain' to do the re-vegetating for us, we have done some small-scale experimental planting and seeding.

In September 2001, following advice from our consultant the late Professor Winterhalder, small 'plantations' were established in ten of the areas we had previously treated. In most we put in four spruce seedlings, one alder (a nitrogen fixer) and one pine or tamarack. These were taken from the right-of-way along the Kisseynew Lake road during a very wet spell. To date, survival in the plantations has been very good. A grass fire in June 2010, which reached the west end of the Balsam plantation, killed the pine and the alder and singed one of the spruce. In 2012, five pine seedlings were noted in the immediate vicinity of the burned pine – presumably derived from its cones. All are doing well and were up to 60 centimetres high in 2016. Vandals broke off the main trunks of the two pines at the Hapnot plantation at knee-height in 2010, but growth of the lower branches continues – the tallest is now just over 3.5 metres high. It is of interest to note that growth and state of health in the plantations varies from area to area, and closely parallels the variation in area 'vegetation-cover status' (see appendix 4).

Plantation conifers in some areas categorized as 'best' (such as Knight and Knight North) are very healthy and 5-6 metres high, while those our 'poor' areas (such as Rock Cut and First Avenue) are more sickly-looking and are up to only a little more than a metre high. Pines at the Balsam and Knight plantations produced cones for the first time in 2008. All our plantation pines now have cones. The tallest spruce in our Knight North plantation produced masses of cones in 2009 – these were the first spruce cones to have appeared in any of our treated areas. In 2016, cones were noted on spruce at six plantations.

Pine and spruce cones were scattered in seventeen of our areas in 2002 through 2004. Germination has taken place in fourteen of these areas. Some of the pine seedlings from cones scattered by Saskatchewan Ministry of Environment personnel at our Knight North area in February 2002 are now 5-6 metres high. Pine seedlings in some of the other areas are 4-5 metres high. A spruce at our Second Valley area is 2 metres high. The pines at the Knight North area produced cones for the first time in 2008. Pine cones have since been noted at nine areas.

In 2003, 2005-2007, 2012 and 2013, local Cubs and Beavers planted hundreds of pine and spruce seedlings – as well as several other species – at the Second Valley, Reservoir Hill, Phantom, Balsam/Esso, Phantom North and Driving Range areas. Survival rate for the conifers has been high – probably better than 90% in most areas. Pines in some areas are now up to 2.95 metres high. Since 2010, some have produced cones. Spruce are up to 2.55 metres high. In 2013, spruce cones appeared for the first time at the Balsam and Second Valley areas. Results at Second Valley are patchy - mortality for both spruce and pines is high at square 1, but healthy spruce up to 1.9 metres high are quite widespread at squares 5, 6 and 8. It is no longer possible to distinguish the Cub and Beaver spruce and pines from the many self-seeded conifers that are coming through in the Phantom area. This year - for the first time, a second generation of small pine seedlings was noted in association with a parent Cub/Beaver pine at the Esso area.

Spruce seedlings from SaskPower's Shand Greenhouse were supplied to us by Saskatchewan Ministry of Environment Creighton office personnel in 2005. They were put in by Green Project staff at three of our areas. Those at the Balsam and Railroad areas and are doing quite well and are up to 2.05 metres high. Some are healthily green and filling out (particularly at Balsam), while others are smaller, thinner and less regular, and tend to be a bit yellowish. Those put in at the Triple Seven area were buried during HMI landscaping activities in the fall of 2008.

In April 2009, Donna Lundquist of the Saskatchewan Ministry of Environment donated 14 kilograms of jack pine and white spruce seeds. These had been collected in 1995 and 1978 respectively, and were being removed from inventory because of their low (estimated 40%) viability. They were scattered in six of our areas by Green Project staff on April 25, 2009 and by Creighton grade 4 students at the Sandbar area June 8, 2009. Seedlings have come through in all of the areas. Pines at the Railroad and Hilary areas are now a little over 2 and 2.5 metres high respectively. Pine cones were noted for the first time in 2013 in four of the areas, and are now present in all seven areas. Spruce are generally smaller and sparser – and so far lack cones.

Supplementary documentation on the above, and on some of our other planting and seeding projects is available on request, and will shortly be posted on our web site.

Scientific Studies

As noted above, many of our areas have responded very well to the limestone treatment, others are coming along more slowly, while in a few the response has been minimal. What accounts for this varying response? Might it be due to variations in the base-metal content of the soil? What treatment in addition to the application of crushed limestone might be needed to enhance germination and growth of woody species in our 'slow' and 'poor' areas – and to encourage growth of understory species?

Our consultant Professor Keith Winterhalder made brief visits to Flin Flon in the summers of 2000 through 2003. He monitored vegetation growth and pH changes in the soil in areas we had treated – he also checked up on experimental plots he had established south of Creighton in 1994 and 1997. He submitted reports on his findings to the Green Project and to HMI in 2001 through 2004. At the time of his death in October 2005, he had been conducting greenhouse experiments on mixtures of Flin Flon soils with other additives. Manitoba Conservation ecosystem monitoring specialist Geoff Jones visited Flin Flon in 2008 to resume monitoring vegetation on the transect lines set up by Professor Winterhalder. A detailed report on this work was submitted in June, 2009. A further five days of field work was carried out in July, 2009. We were saddened to learn that Geoff passed away in January, 2010.

Following preliminary discussions with HMI and Green Project coordinators in late 2007, members of the faculty at the University of Saskatchewan's Department of Soil Science drafted a proposal for a multi-year research project aimed at significantly expanding on the work initiated by Professor Winterhalder. Funding for a five-year project was

secured from HMI and the Natural Sciences and Engineering Research Council of Canada (NSERC).

In December 2013, Green Project and HMI personnel were briefed by faculty and students at the Saskatoon campus on aspects of their project. While earlier broad-scale studies had shown that anomalous metal contents in soils fell off to background levels at distances up to around 100 kilometres from the smelter, the present study shows that metal values within 5 kilometres are extremely variable and seem to depend more on factors such as local topography and soil character than on distance from the source.

A number of metals have been have been analysed for - with zinc and copper values found to range up to around 15,700 and 12,800 parts per million respectively. Metal speciation studies have been carried out at the Canadian Light Source synchrotron facility on campus – concentrating on zinc, which has been recognized as a key factor in limiting natural revegetation. Samples studied include a variety of untreated Flin Flon area soils. Studies were also carried out on changes in metal speciation following the addition of crushed limestone and a variety of other amendments.

Planting and seeding experiments were carried out in the field as well as in growth chambers on campus. A variety of amendments such as smectite, meat and bone-meal biochar and municipal compost were tried – in addition to the crushed limestone and fertilizer. The general conclusion is that any treatment adopted will depend on local topography and soil conditions – and that these and other parameters need to be characterized in detail before embarking on any large-scale treatment project.

Green Project coordinators had no direct contact with the Saskatoon soil scientists in 2016.

With the thought that tree-rings would likely preserve a record of changes in air-borne metal particulates over time, the Green Project asked Donna Lundquist of the Saskatchewan Ministry of Environment to do some coring to determine age ranges of trees in our area. Any future dendrochemical study would need to have access to trees significantly older than say 90 years (that is, they would have been well established prior to the start of local smelting operations in 1930). Trees in the immediate Flin Flon – Creighton area tended to be not more than about 65 years old – but some within 25 kilometres of the smelter complex are as much as 150 years old, and so might be suitable for such a study.

A study carried out on behalf of HMI by Intrinsik Environmental Sciences Inc. on the health implications of elevated levels of some metals and other elements in the soils of Flin Flon and Creighton, was referred to in our 2007-2010 Reports of Activities. The final study report was released in June, 2010. This, together with other information on the study is available at www.flinflonsoilsstudy.com.

Photography

Pairs of 'before-and-after' pictures illustrate in a dramatic way how effective the limestone treatment is proving to be. At left above is a view looking north at our South Hudson area taken shortly after treatment in the summer of 2005. At right is the same scene in August this year. During our first sixteen project years we took 2,872 pictures, and in 2016 we took an additional 112. These will serve as a permanent record of the project, and are being used for public relations purposes.

Google Earth imagery gives us another perspective. We treated our Creighton North area in 2002-2004. The image at left below is from 2002, the one at right is from 2016.

Public Relations

Our website – www.greenproject.ca – has been updated and can be adjusted for viewing on desktop computers, tablets and on mobile phones. Our PowerPoint presentation has been updated and can be viewed via our website. A brief item on the Green Project appeared in the June 16 issue of 'The Reminder'.

Future Plans

Because almost all areas around Flin Flon and Creighton that were readily accessible to our mainly student workforce have by now received the limestone treatment, only minor clean-up operations – using adult community volunteers – are planned for 2017. Monitoring of the progress of vegetation growth in treated areas will be ongoing. All relevant data relating to the 17-year history of the Green Project will be archived at locations that will be accessible for future research purposes. We plan to submit stories on aspects of the Green Project to a number of publications.

Additional Information

Please contact project coordinators:

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and check out our web site at: www.greenproject.ca

APPENDIX 1: Organizational Background and Procedure

In the late 1960s and early 1970s, botanists at Laurentian University – among them our technical consultant, the late Professor Keith Winterhalder – found that the application of crushed limestone to the barren acidified and metal-contaminated soils around Sudbury led to the regeneration of vegetation. A major program of limestone application since then has led to a transformation of the Sudbury landscape.

In the early 1990s, Rena Gummerson and later Cathy Hynes of the Creighton/Denare Beach Economic Development Committee contacted Professor Winterhalder to see if he might be interested in helping to set up a re-vegetation program in our area. This resulted in his first visit up here in 1994. In 1999, Heather Acres and Clarence Pettersen of Flin Flon School Division thought that re-vegetation would be a good project for their Youth Mentor program, and the Green Project was launched with the support of the School Division. Hudson Bay Mining and Smelting Company Ltd. (now Hudbay Minerals Inc. - HMI) and the Flin Flon Economic Development Commission generously provided funding to bring Professor Winterhalder up here in October 1999. He spoke to a number of groups and generated a high level of interest and enthusiasm. A community-based consultation group was formed, and planning meetings were held in March and April 2000. McKeen's Trucking generously donated 130 yards of crushed limestone, and this allowed us to put our first groups of students to work in the field in May of that year.

Since 2000, members of the consultation group have included: Flin Flon School Division, Creighton School Division, City of Flin Flon, Town of Creighton, Flin Flon and District Environment Council, HMI, Saskatchewan Ministry of Environment, and various community group leaders and members.

The first stage in planning our field operations involves checking out maps and air photographs. From these we get a general idea as to which areas might be suitable for treatment. We then ground-check the areas. Once their suitability has been confirmed, the crushed limestone is trucked in. Volunteers fill their pails at the dumps and spread the limestone as evenly as possible. The coordinator/supervisor makes sure no gaps are left. Work continues until the designated area is completely covered.

APPENDIX 2: Environment and Science

In and around the communities of Flin Flon and Creighton[1], there are large areas with little or no vegetation. Old tree stumps show that these areas were once forested.

In the 1920s and '30s when our communities and the smelter complex were first established, many trees were cut for fuel and lumber. Others were cut to make fire breaks, or were burned in forest fires. As production from the Flin Flon and other mines increased, so did the amount of sulphur dioxide smoke from the smelter. The smoke is harmful to vegetation, so the forest was not able to recover. The increasing acidity and metal content of the soil meant that only a very few hardy types of plant were able to survive. As the plants died, the thin topsoil washed away.

High levels of metals such as copper and zinc in the soil are toxic to plants[2]. This toxicity is accentuated by acidity, which makes the metals more soluble, and therefore more accessible. When seeds germinate in metal-contaminated soil, growth stops immediately on contact with the toxic soil solutions. The carbonate ion in the limestone tends to neutralize soil acidity, thus making the metals less soluble, and less toxic. Another component of the limestone, calcium, contributes to reducing soil toxicity by competing with zinc ions for uptake by plant roots. Calcium ions also have a strengthening effect on the plasma membranes in the root cells. This membrane is responsible for determining what is absorbed by the roots.

Since the early 1970s, Hudson Bay Mining and Smelting Company Ltd. (now Hudbay Minerals Inc. - HMI) spent hundreds of millions of dollars on upgrading technology at the smelter complex, with the result that emissions of sulphur dioxide and metal oxide dust were significantly reduced. The natural vegetation started to slowly recover. Our project is accelerating this recovery. In June 2010, the copper smelter was closed down, resulting in a complete cessation of gaseous and particulate emission from the stack.

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[1] *Flin Flon and Creighton are situated on either side of the Manitoba/Saskatchewan boundary about 600 kilometres north of the Canada/US border. A large copper-zinc ore body was discovered at Flin Flon in 1915, and production – which started in 1930 – continues to the present day.*

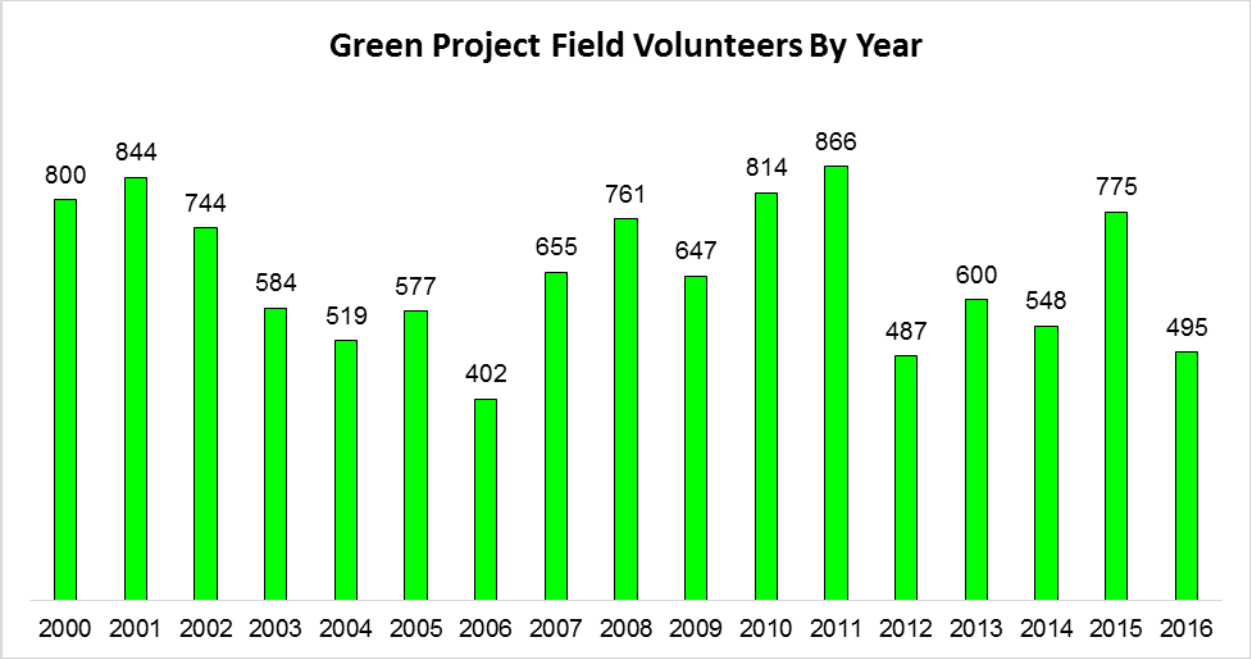
[2] *This paragraph is from information supplied by the late Professor Winterhalder.*

APPENDIX 3:

Personnel Summary Tabulation ~ 2016

Group	Sessions	Number*1
McIsaac School	7	189
Ruth Betts School	7	151
Creighton School	5	143
SITP*2	1	12
Total	**20**	**495**

Personnel Distribution ~ 2000-2016

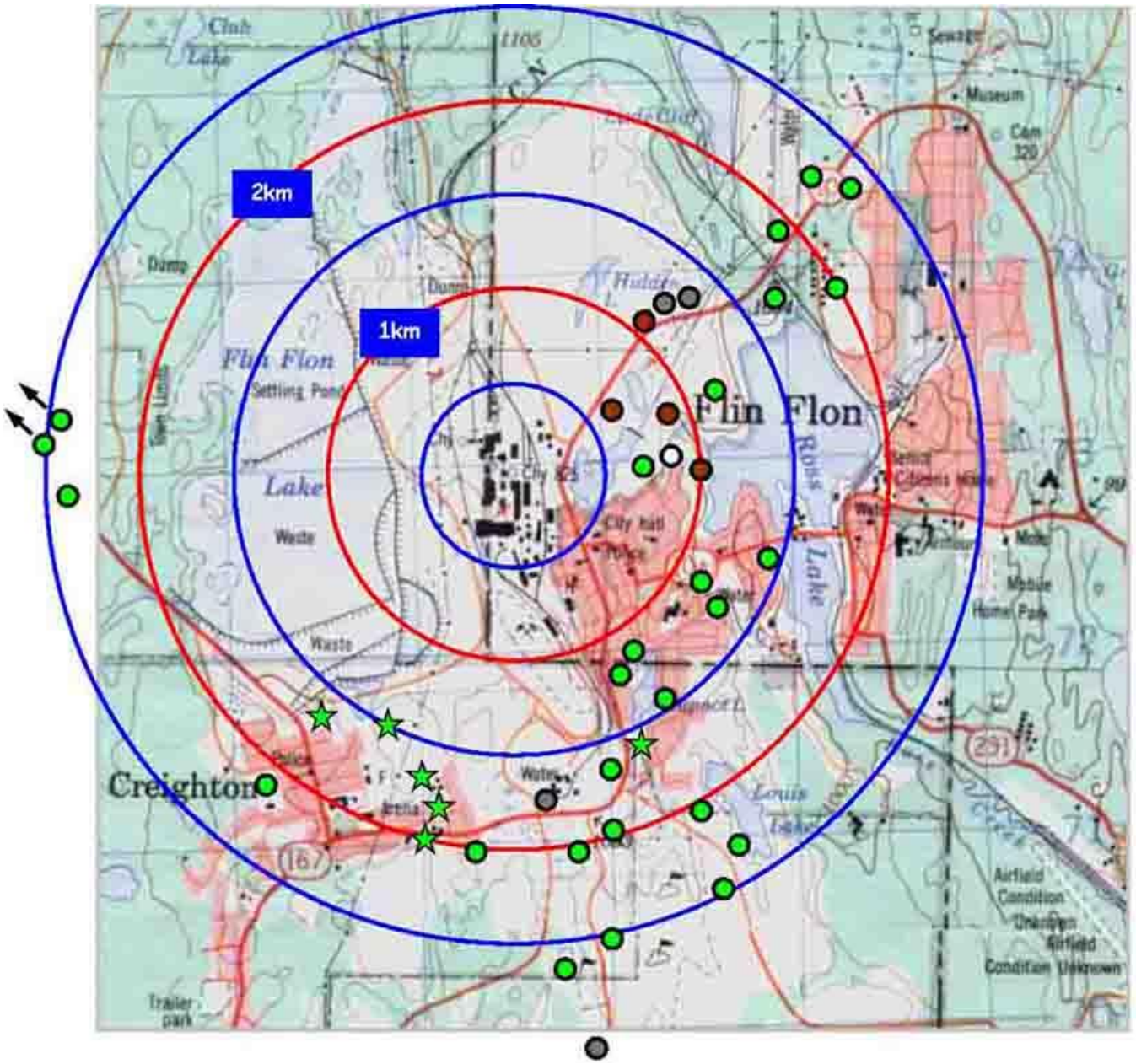


Total to date ~ 11,118*1

*1 *Because some individuals worked in more than one session, the actual number of participants in the Green Project is less than this.*

*2 *City of Flin Flon – 'Summer-in-the-Parks' program*

APPENDIX 4: Vegetation-Cover Status by Area at Fall, 2016



Green stars – best, green circles – good, gray circles – promising,
brown circles – poorest, open circles – awaiting results.

Large circles are centred on HMI's stack (half-kilometre intervals).