BEAVERLODGE PROJECT

Cameco

Beaverlodge Mine Site

Path Forward Report

Prepared for:
Canadian Nuclear Safety Commission
&
Saskatchewan Ministry of Environment

Prepared and Submitted by:
Cameco Corporation
with support from
SENES Consultants Limited

December 2012

BEAVERLODGE PATH FORWARD REPORT SUMMARY

PREFACE

Cameco Corporation has developed a path forward for preparing the decommissioned Beaverlodge mine properties for release into the provincial Institutional Control (IC) program. This document provides a comprehensive review of the actions that were considered and those that are proposed to be undertaken prior to the eventual transfer of the decommissioned properties into the IC program.

In arriving at the specific path forward actions to be implemented, extensive consultations have been undertaken with both the regulatory agencies and stakeholders. The process was governed by the Beaverlodge Management Framework, which is intended to provide a systematic, transparent and justifiable process for assessment of potential remedial activities prior to transfer of the licensed Beaverlodge properties into the provincial IC program. Those consultations resulted in the development of numerous potential remedial options for consideration, which are presented in this document along with the justification for the activities proposed to be undertaken during the next licensing period to facilitate transfer of properties into the IC program.

Within the Management Framework, the relative residual risk to the environment and/or people was assessed for each individual property or group of properties. If a particular risk at a given property was not considered acceptable, remedial options to mitigate that risk were identified and considered. A period of monitoring will follow the implementation of any remedial activity in order to verify that site-specific performance objectives are being achieved. As stated in the Beaverlodge Management Framework if the objectives are met at a given property, that property would be proposed for transfer to the IC program. If the site-specific performance objectives are not met, then the Management Framework requires additional site-specific risk assessment be completed to determine if residual risks are acceptable or if additional remediation is warranted prior to transfer of the property to the IC program.

EXECUTIVE SUMMARY

Background

The Beaverlodge mines and mill in northern Saskatchewan were operated by Eldorado Mining and Refining Limited (later known as Eldorado Resources), a federal Crown corporation, from 1952 to 1982, after which they were decommissioned according to the regulatory requirements of the day.

Decommissioning activities were complete by 1985, and the properties have subsequently been in a transitional monitoring phase, consisting of:

- routine environmental monitoring;
- conducting targeted environmental investigations as needed; and,
- performing maintenance and other activities to investigate and address outstanding issues and ensure the properties are and remain safe and secure for people and the environment.

Since 1988, management of the decommissioned properties has been the responsibility of Cameco as the site licensee. Canada Eldor Inc., a subsidiary of the federal government-owned Canada Development Investment Corporation, is wholly responsible for financial liabilities associated with the Beaverlodge site and funding of the licenced activities.

Currently there are 62 licensed properties associated with the Beaverlodge site, ranging in size from one to 30 hectares. The main mine and mill properties are located eight kilometres east of Uranium City. Other Beaverlodge properties include those associated with the Dubyna mine, the Hab mine, the Bolger/Verna area and the Fulton Creek watershed, which are generally situated to the north and east of the main mill property.

The decommissioned properties are located within two adjacent, but distinct watershed systems—Ace Creek and Fulton Creek—both of which drain into Beaverlodge Lake. Within the Ace Creek Watershed there are numerous small satellite mines sites which have remnant waste rock piles; this watershed is also the location of the main underground mine and associated waste rock pile as well as the former mill site. The main Beaverlodge tailings management areas for the mill were located in the Fulton Creek watershed; Marie and Fookes reservoirs, in particular.

It is Cameco's intention, as supported by Canada Eldor, to transfer responsibility for long-term monitoring and maintenance activities of the Beaverlodge properties to the Province of Saskatchewan's IC program, which was established in 2007. The property would then be managed by the province within the IC program registry. As part of IC program, the proponent is responsible for providing the financial resources to the IC Monitoring and Maintenance Fund as well as a separate Unforeseen Events Fund. The level of funding is established in consultation with the province.

Beaverlodge Management Framework

The Beaverlodge Management Framework and supporting documents were developed in 2009 by the Joint Regulatory Group (JRG), which includes the CNSC, Environment Canada, Saskatchewan Ministry of Environment, the Department of Fisheries and Oceans Canada, and Cameco. The intent of the Beaverlodge Management Framework is to provide clear scope and objectives for the management of the Beaverlodge properties and a systematic process for assessing site-specific risks to allow decisions to be made regarding the transfer of Beaverlodge properties to IC. The framework has been reviewed by public stakeholders, including the Environmental Quality Committees (EQC) and residents and leaders of the Uranium City community.

Remedial options developed and assessed

A remedial options workshop was held in 2009 to bring together regulatory and non-regulatory stakeholders to determine what, if anything, could be done on the decommissioned Beaverlodge properties to improve the environmental conditions. The workshop was attended by regulatory and other government agencies, Cameco, third-party consultants, the Environmental Quality Committee, and Uranium City residents. During the 2009 workshop a list of potential remedial options was developed for consideration and it was recognized that additional site specific information was required before decisions could be made regarding the benefit of implementing remedial options.

Following the 2009 workshop, the Beaverlodge Quantitative Site Model (QSM) was developed in order to help quantify the environmental benefit and risk associated with potential remedial activities. The QSM provides insight into the interactions between potential contaminant sources and transport in the Beaverlodge area watersheds.

In examining the various remedial options, the QSM made predictions regarding the expected benefits of implementing various remedial activities on the local and downstream waterbodies. The QSM results were then compared to the baseline option (showing natural attenuation) in order to assess the potential environmental benefits and other effects of implementing each option alone or in combination with other options.

In general, the water quality timeline plotted for many of the potential remediation options examined showed some localized minor improvements in the predicted levels of key constituents of concern (radium-226, uranium and selenium) in the immediate local downstream water body; however, the predicted benefit to downstream waterbodies including Beaverlodge Lake was negligible over the 150 year assessment period.

A scoping level engineering cost assessment was completed for the remedial measures identified during the 2009 Beaverlodge remedial options workshop and made available for the follow up remedial options workshop conducted in 2012. The range of costs developed for the considered remedial activities ranged from $75,000 to $55,000,000.

The second remedial options workshop assessed the expected benefit of implementing potential remedial options, as provided by the Beaverlodge QSM, along with the expected cost of implementing various options identified in the cost assessment described above.

The results from the 2012 workshop were considered during the development of the path forward presented in this document. Some of the general conclusions of the 2012 workshop are that, while there may be a few small scale activities that show some localized water quality improvement, based on the technical studies and workshop results it has been concluded there remains no reasonable means of meaningfully accelerating the recovery of Beaverlodge and downstream lakes.

Remedial options selection process

The path forward for moving the Beaverlodge licensed properties into IC was developed by evaluating potential remedial activities using a number of criteria. These criteria include assessment of expected benefits to the local and downstream environment; predicted capital and operating costs; amount of long term maintenance/operation required; level of uncertainty regarding technical feasibility, predicted benefits or costs; regulatory requirements; and social acceptability.

The social acceptability of the remedial options was determined through regular site tours and public meetings that included local residents, regional stakeholders and regulatory agencies. In addition, stakeholder opinion was gauged through the remedial options workshops, which were held in 2009 and 2012 and conducted by third-party facilitators.

At the 2012 workshop, stakeholders were provided estimates on the costs, benefits and potential risks associated with a series of potential remedial options, and then were asked to provide their feedback on the reasonability of each option. While the consensus of the stakeholders in this process was that “do nothing” was not an acceptable option, there was a clear mandate to ensure that those options which may be undertaken needed to be reasonable and realistic from a cost perspective in relation to the predicted benefit. They concluded that, ultimately, the recovery of the Beaverlodge properties and the receiving environment will continue to be a long-term proposition.

Through these initiatives, public stakeholders were effectively informed and engaged regarding the future of the Beaverlodge properties. Their concerns and aspirations with respect to the remedial options were captured and considered. This feedback influenced decisions made regarding which remedial activities were considered to be both reasonable and socially acceptable. The engagement process, including the outcomes of the workshops and other initiatives, support the path forward plan.

Path Forward

Informed by the workshop process and other engagement activities, a path forward was developed by Cameco in consultation with Canada Eldor. While there are no reasonably practical measures, taking into account the Management Framework, that can be implemented to meaningfully reduce the overall recovery time of Beaverlodge Lake and other downstream water bodies, there are some practical things that can be done to: 1) assure the properties have been decommissioned in accordance with good engineering practice; and, 2) to incrementally improve water quality in local water bodies.

Specific remedial activities that have been proposed for implementation include:

- Creation of a channel through Bolger waste rock pile to allow Zora Creek to return to its normal flow path. This will reduce water contact with waste rock and the release of uranium to Verna Lake resulting in local incremental improvement in water quality in Verna Lake.
- Identified flowing boreholes on all Beaverlodge properties will be plugged to reduce groundwater outflow from former mine workings. This is predicted to result in a small but incremental improvement in local water quality.

Several other remedial activities will be applied within the Beaverlodge licensed areas. Caps on all vertical mine openings will be replaced with engineer approved caps to reduce physical risks associated with individuals or animals encountering a vertical mine opening where the cap has failed prematurely. Gamma surveys will be performed across all the properties to identify areas of elevated gamma levels where an unacceptable radiation risk may occur were individuals to occupy these areas for significant periods of time in the future. Areas that contain elevated gamma fields will be assessed in this context for remediation within the Management Framework. These remedial activities will be undertaken prior to the properties being transferred to the IC program.

Furthermore, while monitoring water quality will continue at the well-established monitoring stations in the Beaverlodge study area, Cameco, in partnership with Saskatchewan Research Council, will engage the JRG and local stakeholders to establish a regional monitoring program. The program would be initiated in the near term, following acceptance by the JRG, and will continue after all licensed properties have been transferred to the IC program. The long term regional monitoring program will provide a tool for assessing the long-term recovery predictions made in this document for Beaverlodge Lake and the downstream environment.

Performance Objectives

A set of site-specific performance objectives was derived in order to assess the performance of implementing the proposed remedial measures. The performance objectives serve two purposes; first they will be used in the short term (5 to 7 years) as a site specific target for assessing the effectiveness of remedial activities that are implemented; secondly they will be used after the properties have been transferred to the IC program to compare long term recovery of the properties and downstream environment to predictions.

The effects of uncertainty in key parameters in the Beaverlodge QSM on water-quality predictions were examined to establish bounds on the predictions which were then used as the basis for determining reasonable site-specific water-quality objectives. In accordance with the Beaverlodge Management Framework, short term performance objectives will be used to evaluate the success of those remedial options being implemented. Once short term performance objectives are achieved they will form the basis for transferring the sites to the IC program. If short term performance objectives are not achieved then residual risks will be assessed in accordance with the Beaverlodge Management Framework as to whether or not further remedial action is required prior to transfer to IC.

This path forward plan provides clear direction concerning further remedial activities on the Beaverlodge properties to facilitate their transfer into the IC program. A number of the peripheral licensed sites will require little or no further remediation and we expect to apply for their release to the ICP within five years. It is anticipated those areas requiring additional remediation can be released to the ICP following implementation of the proposed remedial actions followed by a period of monitoring to confirm that short term performance objectives have been met (within 10 years).

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

Page No.

LIST OF FIGURES (Cont`d)

Page No.

LIST OF FIGURES (Cont`d)

LIST OF FIGURES (Cont`d)

Page No.

LIST OF FIGURES (Cont`d)

Page No.

LIST OF FIGURES (Cont`d)

Page No.

1.0 INTRODUCTION

In the following report, the remedial action plan developed by Cameco in consultation with Canada Eldor for the Beaverlodge study area is presented along with supporting discussions. Chapter 1 outlines the current project, provides a brief site overview as well as discussion about the Beaverlodge Management Framework; Chapter 2 assesses remedial measures considered for each site within the Beaverlodge study area; Chapter 3 presents the entire Beaverlodge remedial plan; and, the resulting site-specific performance objectives are derived and presented in Chapter 4.

1.1 BEAVERLODGE PROJECT OVERVIEW

The Beaverlodge uranium mine/mill and associated properties, located northwest of Beaverlodge Lake in northern Saskatchewan (shown in Figure 1.1-1), were operated by Eldorado Mining and Refining Limited for nearly 30 years between 1952 and 1982. Operations ceased in 1982, at which time Eldorado Nuclear Limited initiated site decommissioning activities. The site was decommissioned over the 1983 to 1985 period to meet the regulatory requirements of the day and post-decommissioning monitoring was subsequently initiated. In 1988, Cameco Corporation (Cameco) took over the responsibility for the Beaverlodge properties on behalf of Canada Eldor and has continued to carry out routine environmental monitoring as well as targeted environmental investigations and has performed maintenance work, as required, on the decommissioned facilities. While Cameco is responsible for managing the site as the site licensee, Canada Eldor, which was created as a subsidiary of the Canadian Development Investment Corporation (CDIC) around 1988, remains wholly responsible for financial liabilities associated with the Beaverlodge site. It is the intention of Cameco and Canada Eldor to turn over long-term monitoring and maintenance activities for the Beaverlodge site to the Province under its Institutional Control (IC) Program.

In 2007, Saskatchewan developed *The Reclaimed Industrial Sites Regulations* to enforce the Institutional Control (IC) program whereby decommissioned mining properties in the province that meet certain criteria could be transferred to the Province for long-term monitoring and maintenance. The two primary components of the IC program are the Institutional Control Registry and the Institutional Control Funds: the Monitoring and Maintenance Fund and the Unforeseen Events Fund. The primary objectives of the IC program are to:

- Protect human health and safety;
- Protect the environment;
- Ensure future generations are not burdened with the costs of long-term monitoring and maintenance for current mining development;
- Be sustainable; and

- Recognize federal jurisdiction regulatory roles and responsibilities for national and international obligations.

In 2012, Cameco contracted SENES Consultants Limited to prepare supporting documentation for Cameco's proposed remedial path forward for the Beaverlodge area, with the intent of preparing the transfer of the licensed properties to provincial control through the IC program. This document contains Cameco's remedial path forward along with supporting discussion.

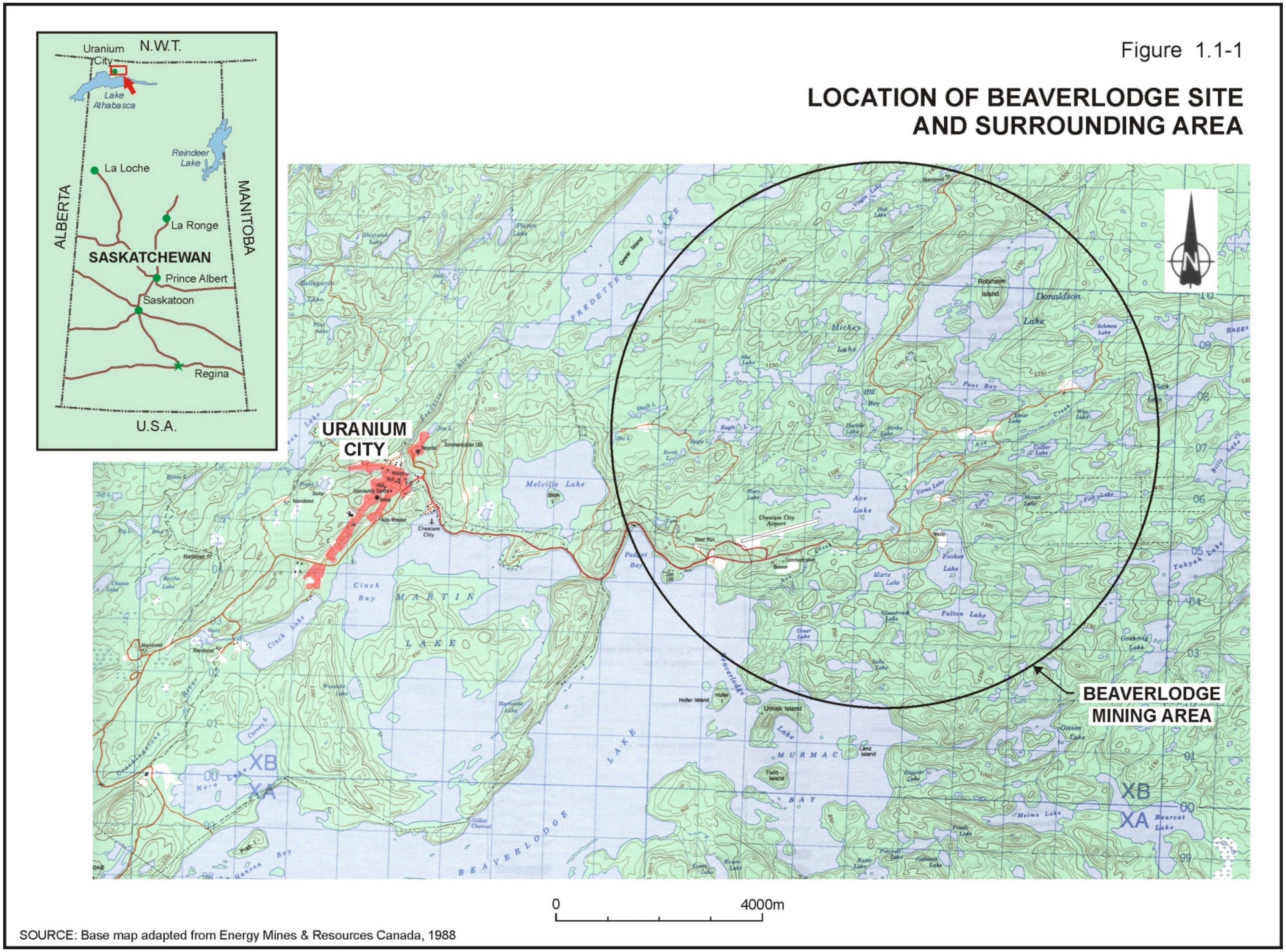


Figure 1.1-1
LOCATION OF BEAVERLODGE SITE
AND SURROUNDING AREA
Uranium City
N.W.T.
Lake Athabasca
Reindeer Lake
La Loche
La Ronge
ALBERTA
MANITOBA
SASKATCHEWAN
Prince Albert
Saskatoon
Regina
U.S.A.
URANIUM CITY
BEAVERLODGE MINING AREA
N
0
4000m
SOURCE: Base map adapted from Energy Mines & Resources Canada, 1988

1.2 BEAVERLODGE SITE OVERVIEW

The CNSC licensed Beaverlodge study area properties are identified in the "*Beaverlodge Mine and Mill Site Waste Facility Operating License WFOL-W5-2120.0/2012*" and include the main facilities in the Lower Ace Creek watershed (i.e., the Fay-Ace-Verna mine and mill facilities), satellite mines in the Upper Ace Creek watershed (i.e., the Hab, Dubyna and Bolger mines) and the tailings management area in the Fulton Creek watershed. Figure 1.2-1 shows the location of the Ace Creek and Fulton Creek watersheds. As can be seen, water discharges from both of these watersheds into Beaverlodge Lake. Water exiting Beaverlodge Lake flows through Martin Lake, Cinch Lake and Crackingstone River before entering into Lake Athabasca.

During the lifetime of the Beaverlodge operation, ore was extracted from both underground and surface mines that were dispersed over an approximate 8.5 km radius, mainly north and east of the main production shaft (Fay shaft) located adjacent to Ace Creek near its confluence with Beaverlodge Lake. The locations of the principal satellite mines and the surface facilities at the main mine/mill complex are shown in Figure 1.2-2. Located within the Ace Creek watershed are the former main mine complex (Fay-Verna mine) and mill, waste rock disposal areas, and a number of satellite mines including (1) the Hab mine located in a small watershed area that includes Beatrice and Pistol lakes, which drain to Mickey Lake and eventually Ace Lake; (2) the Dubyna mine area located within a small watershed that drains Schmoo Lake and Dubyna Lake to Ace Creek upstream of Ace Lake; and, (3) the Bolger mine area, which is located within a small watershed that drains Moran Lake and Zora Lake to Verna Lake then into Ace Lake. There are other satellite mines shown on Figure 1.2-2; however they were small scale developments and are not Eldorado properties. The Fay-Verna underground mine complex extended from Beaverlodge Lake to Verna Lake and consisted of three shafts (Fay, Ace and Verna). The mill site for the Beaverlodge area was also in this area, just west of the Fay shaft below Ace Lake. There are additional minor sites not shown in this map, however, they have already been released to the IC program; locations of these properties are shown in Figure 1.3-2.

While the Fulton Creek watershed did not include any mines (except the small 72 Zone mine), it was used as the tailings management system during the operating period of the mine. The system consisted of (1) two reservoirs (Fookes Reservoir and Marie Reservoir) used for tailings solid settling; (2) a man-made pond (Meadow Settling Pond) used for settlement of radium precipitate following barium chloride addition at the Marie Reservoir treatment plant; and, (3) a third reservoir (Minewater Reservoir) that was initially used for tailings deposition and later as a settling pond for treated mine water. While tailings were deposited in Minewater Reservoir beginning in 1953, tailings deposition was switched to Marie Reservoir and subsequently Fookes Reservoir in the Fulton Creek watershed starting in 1954. Treatment of the tailings effluent did not commence until twenty-three years later in 1976/1977. Water within the Fulton Creek watershed flows from Fulton Lake (an un-impacted lake upstream of Fookes Reservoir) to Fookes Reservoir, from Fookes Reservoir along Fulton Creek into Marie Reservoir, passes through a fen area (formerly the Meadow Settling Pond), into Greer Lake and finally into Fulton Bay of Beaverlodge Lake. Minewater Reservoir has an intermittent discharge that flows to Unnamed Reservoir, which itself discharges into the fen area within the former Meadow Settling Pond.

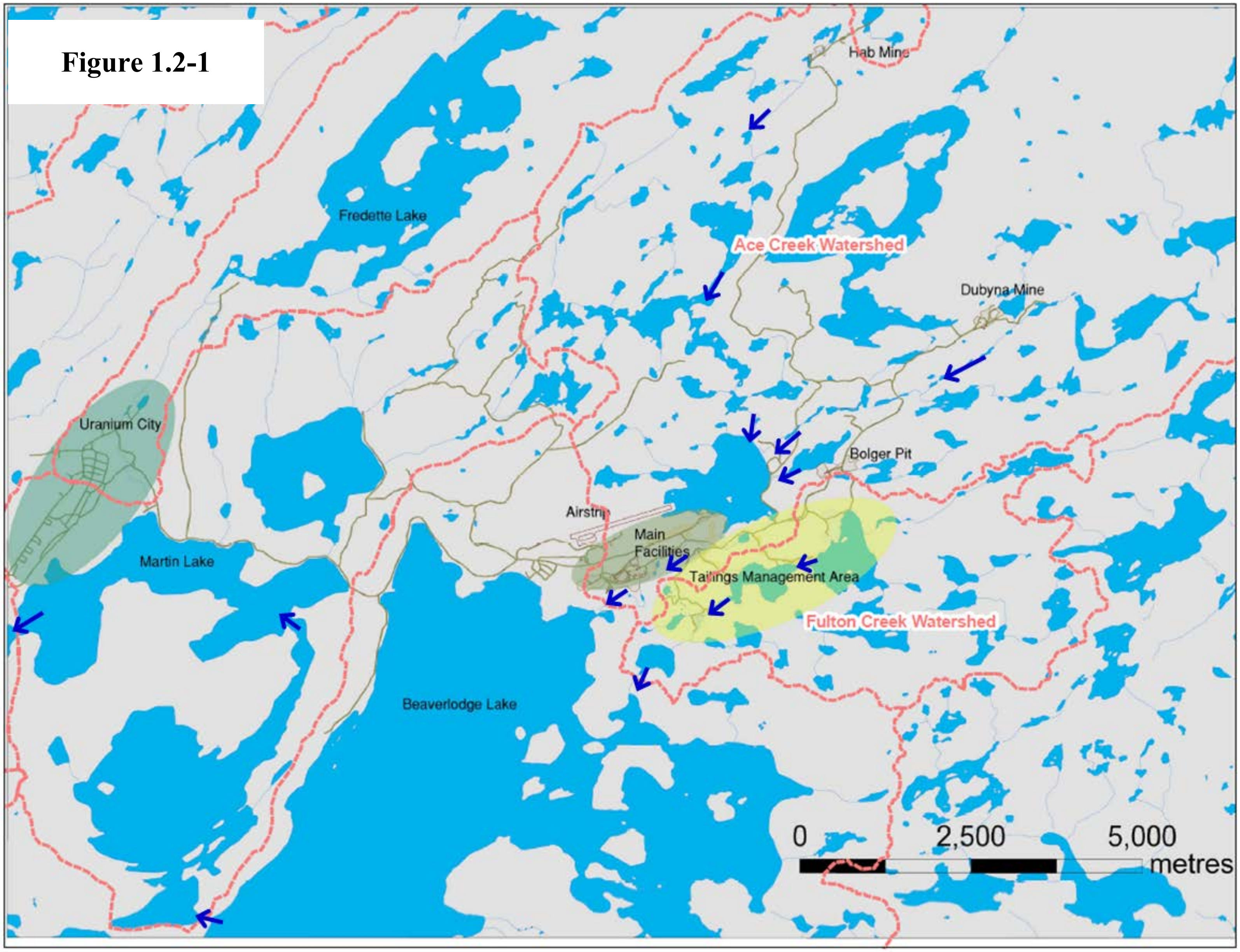
Tailings were deposited primarily in Marie and Fookes reservoirs during the life of the mine although a significant portion of the tailings was also used as backfill material in the underground mines. Some tailings were also spilled on surface during the life of the milling operation from breaks in the tailings lines. Spilled tailings were deposited in the Ace Creek floodplain, within the Lower Ace Creek catchment along the length of the old tailings line to Marie Reservoir, within the Ace Stope area and along the tailings pipeline corridor to Fookes Reservoir. Tailings beaches were also formed at Fookes and Marie reservoirs at the point of discharge. Some of this material was excavated and placed under water during decommissioning work on Marie and Fookes reservoirs. At Fookes Reservoir, a tailings delta remained following removal of a control structure at the outlet of the lake. Waste rock and sand were placed on these tailings to reduce gamma fields as part of the remediation work.

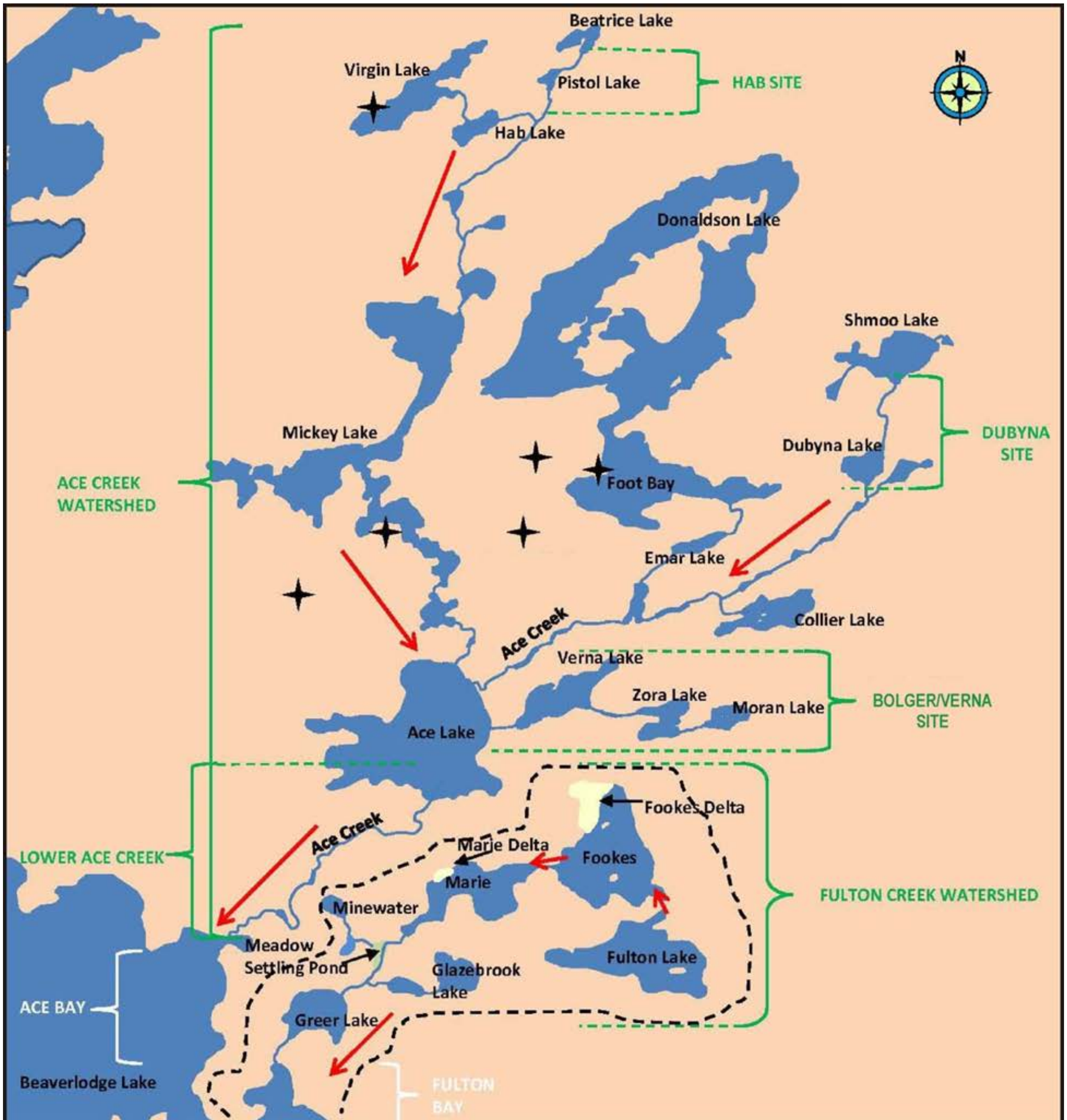
Waste rock disposal occurred on surface in the vicinity of all mine sites throughout the Beaverlodge area. The largest waste rock pile is found within the lower reach of Ace Creek. Other piles are located at the Hab, Dubyna and Bolger mine areas.

Other remediation activities undertaken in the 1980's included; removal of chemicals and hazardous materials from the mine site; demolition of all buildings and shafts; grading of waste rock piles, backfilling of mine adits and capping of mine shafts and vent raises to improve site safety; disposal of waste materials and treatment plant sludges in the underground mine workings; and, burial of the mill foundations under the Fay waste rock pile.

There is an ongoing water quality monitoring program that is carried out to assess conditions at each site. Water quality stations that are routinely monitored at the Beaverlodge mine site are shown in Figure 1.2-3; the majority of these stations have been monitored regularly since decommissioning of the area, however, some of the stations were added to the program in January 2011. The majority of the stations are located in the Ace Creek and Fulton Creek watersheds.

Figure 1.2-1


Hab Mine
Fredette Lake
Ace Creek Watershed
Dubyna Mine
Uranium City
Bolger Pit
Airstrip
Main Facilities
Tailings Management Area
Martin Lake
Fulton Creek Watershed
Beaverlodge Lake
0
2,500
5,000
metres



Legend:

Flow Direction

Non-Eldorado Mines

Figure 1.2-2

LOCATIONS OF SITE, SMALL MINES MAIN MINE/MILL FACILITIES

SOURCE: Adapted from Cameco Corporation, Beaverlodge Conceptual Model Report-Figure 3, April 2010

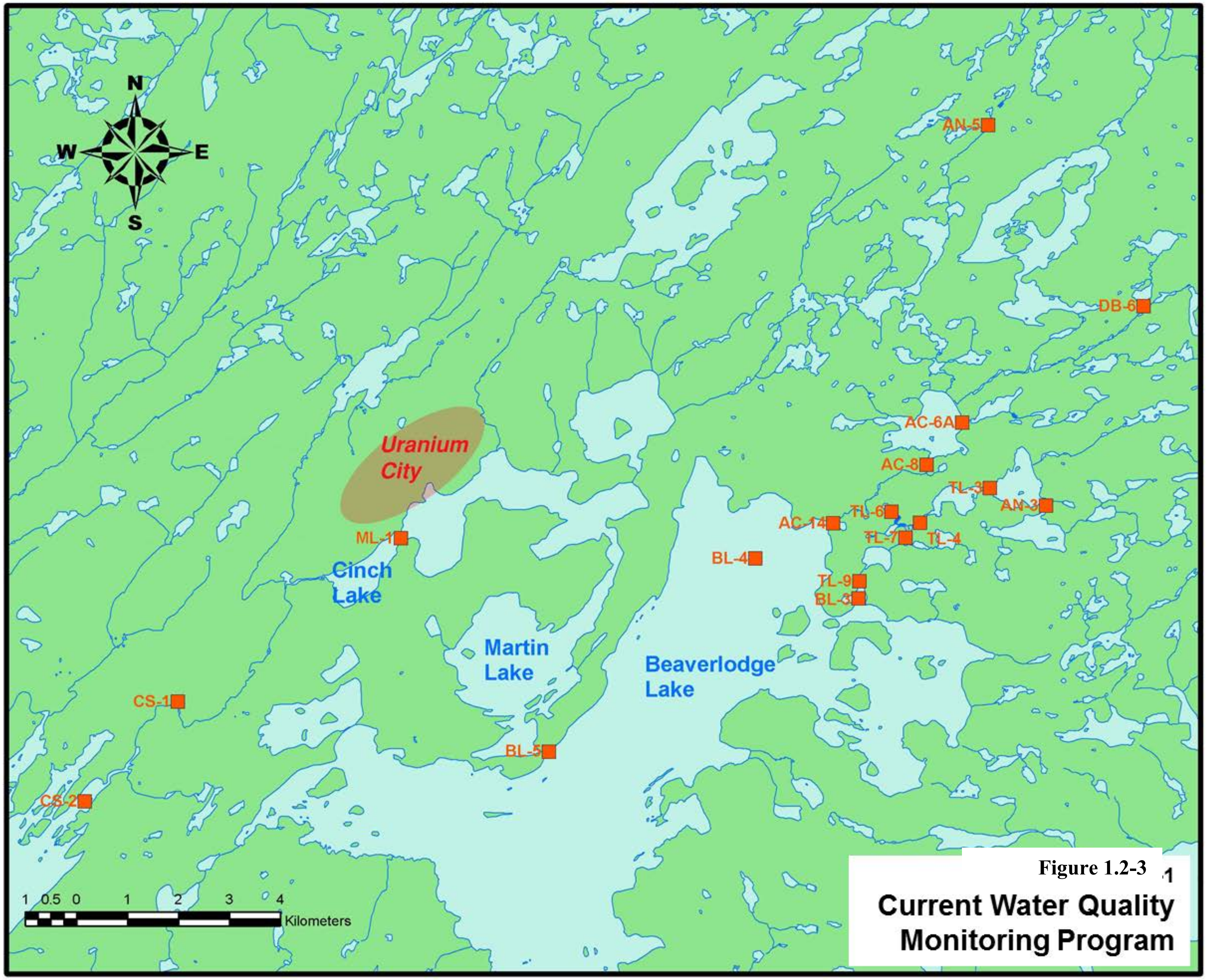


Figure 1.2-3

Current Water Quality Monitoring Program

1.3 BEAVERLODGE MANAGEMENT FRAMEWORK

The Beaverlodge Management Framework and supporting documents were developed in 2009 in consultation with representatives of various federal and provincial regulatory agencies to provide clear objectives for the management of the Beaverlodge properties and a systematic process for assessing site specific risks and determining appropriate remedial measures. The intent of the Beaverlodge Management Framework is to minimize predicted human and environmental risks to acceptable levels and ultimately lead to acceptance of the licensed Beaverlodge properties into Saskatchewan's IC program. The framework was developed by the Joint Regulatory Group (JRG) and Cameco, in consultation with Canada Eldor, and has been reviewed by stakeholders. The management framework official mission statement, management philosophy and objectives are as follows:

Mission Statement:

> Manage the decommissioned sites to achieve release from provincial decommissioning and reclamation requirements, meet requirements for exemption from CNSC licensing, and acceptance into the Province of Saskatchewan's Institutional Control (IC) program, while minimizing human and environmental risks to acceptable levels.

Management Philosophy:

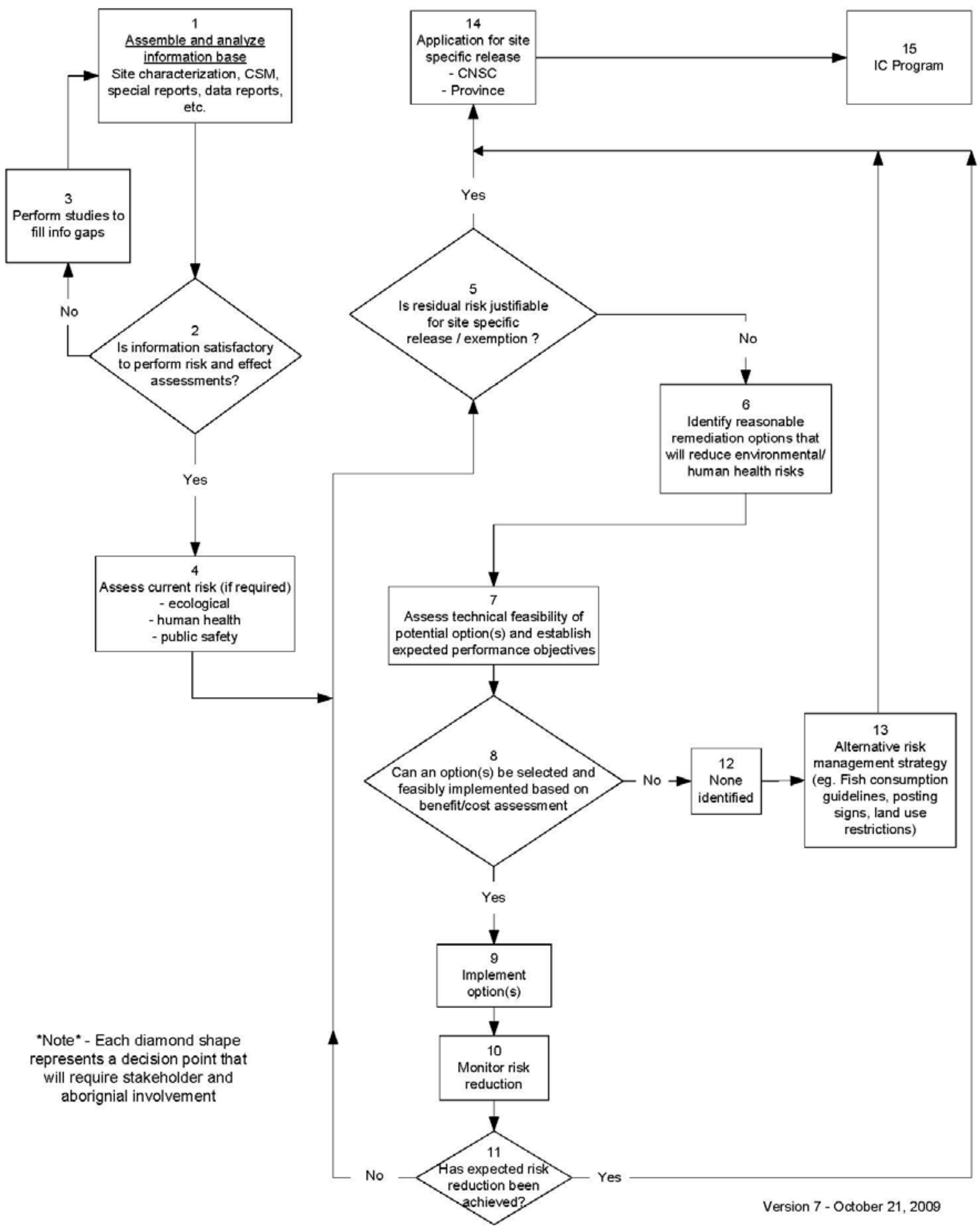
> Recognizing historical impacts exist in the Beaverlodge Lake area, manage the former Eldorado – Beaverlodge properties consistent with Cameco's environment policy and regulatory requirements, while managing risks to meet the ALARA principle (As Low As Reasonably Achievable, taking social and economic factors into account). Given this context, management will be focused on the current licensed properties and specified, adjacent unlicensed areas (Greer Lake, Ace Bay and Fulton Bay of Beaverlodge Lake). The justification for entry into the Province of Saskatchewan Institutional Control program will be based upon a clear and transparent process with evidence demonstrating that the licensed properties are stable, and/or continually improving, and residual risks are managed to levels proportional to the risks.

Objectives:

- Compliance with federal and provincial regulatory requirements
- Management of the properties in accordance with this framework, including the "Former Eldorado, Beaverlodge – Management Decision Flowchart" (Figure 1.3-1)
- To transfer the individual licensed properties to IC on a phased basis as they are demonstrated to meet the IC program requirements
- To manage Greer Lake, Ace Bay and Fulton Bay under applicable federal and provincial jurisdictions, with Saskatchewan Ministry of Environment as the lead. As such, Cameco, in consultation with the JRG, will manage environment, health and safety concerns in those areas in accordance with the management philosophy outlined above.

- Maintain a public outreach program that features proactive stakeholder involvement, including consultation with local communities, First Nations and Métis Nation – Saskatchewan.

Figure 1.3-1 Former Eldorado Beaverlodge Management Decision Flowchart



The Beaverlodge Management Framework was followed successfully to completion for a number of Beaverlodge study area licensed properties; these properties were released to the IC program and are indicated in Figure 1.3-2 by green shading. The properties shown in blue (Martin Lake adits) may be released to the IC program during the current license period and the yellow properties are proposed for release within the next 10 year license period as a result of the Beaverlodge remedial plan outlined in this report. Licensed properties associated with the tailings management area are shown in orange; these properties are expected to be released in the next 10 year period as well.

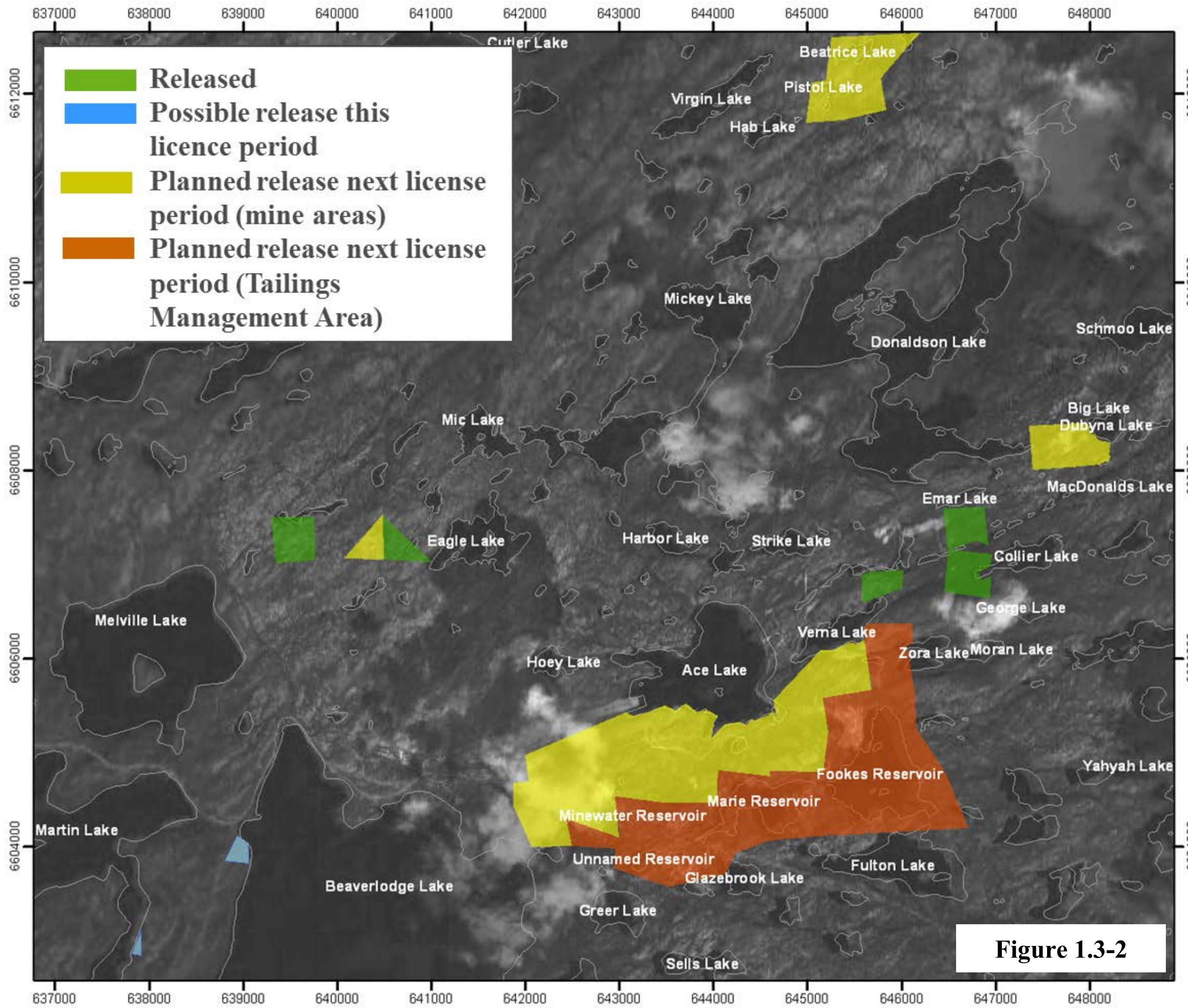


Figure 1.3-2

1.4 SUPPORTING STUDIES

In order to inform this decision making process, a number of studies were completed. The most recent and most significant include development of the Beaverlodge Quantitative Site Model (QSM) (SENES 2012a), preparation of a Beaverlodge Costing Study (SENES & SRK 2012) and facilitation of the 2012 Beaverlodge Remedial Options Workshop (ASKI, SENES & SRK 2012). Details of these three studies including what was involved and how each study helped to inform the development of the Beaverlodge remedial action plan are included in the following sections. Potential remedial measures examined in all three studies included activities such as:

i) covering the sediments in affected lakes with clay, sand or other cover material to reduce the flux of metal and radionuclides into the overlying waters;

ii) dredging lake sediments for disposal in a secure location to reduce the flux of metals and radionuclides from the watershed into surface waters;

iii) consolidating waste rock piles into smaller footprints to reduce the flux of metals and radionuclides transported with precipitation that infiltrates the plies;

iv) applying a cover on waste rock piles to reduce the flux of metals and radionuclides transported with precipitation that infiltrates the plies;

v) isolating or covering exposed tailings spill areas to reduce surface gamma radiation and the flux of metals and radionuclides carried with surface runoff that comes in contact with the tailings;

vi) treating contaminated water and management of treatment sludges to reduce the flux of trace metals and radionuclides to downstream waters;

vii) diverting clean flow around a contaminant source to reduce the flux of metals and radionuclides transported from that site to downstream waters;

viii) plugging flowing and non-flowing boreholes to reduce the flux of metals and radionuclides transported from that site to downstream waters; or

ix) capping of all shafts to meet present day standards to reduce safety hazards and flowing of water into old underground workings.

1.4.1 Beaverlodge Quantitative Site Model (QSM)

The ultimate objective in developing the QSM was to build a tool that will support risk based decision making regarding the benefit of additional remediation of historical contaminant sources at the properties, and that will permit prediction of environmental recovery in Beaverlodge area water bodies. Specific objectives of the QSM were to: (a) enhance the understanding of contaminant sources, transport mechanisms and environmental interactions in the Beaverlodge area watersheds; b) assist in screening conceptual remedial strategies; (c) facilitate establishing environmental performance objectives; and, (d) provide input required for the evaluation of present and future environmental risks. Over 20 studies were completed to collect data which was used to inform the Beaverlodge QSM during development.

As an environmental management tool, the QSM was developed with a user friendly interface to allow easy investigation of the effects of various remedial measures that could be undertaken on licensed properties prior to transfer to the IC program. This remedial measure assessment feature of the model predicts contaminant load reduction as well as future water quality throughout the Beaverlodge study area which results from implementation of selected remedial measures. The Beaverlodge QSM was designed to allow the user to assess the effects of more than 65 different potential remedial activities, either as individual measures or any selected permutations.

In summary, the prime objective in developing the QSM was to provide a tool to assist all interested parties in understanding the relationships between contaminant loads from the licensed properties under current conditions, to evaluate the potential benefit of remedial actions as relates to recovery of the Beaverlodge area lakes and to facilitate the process of moving the properties to the IC program once it is demonstrated that risks are managed and that conditions are stable.

1.4.2 Beaverlodge Costing Study

A costing study was undertaken to assess conceptual level costs of implementing various remedial measures within the Beaverlodge study area. Remedial activities assessed in this way were based on outcomes of a Beaverlodge Remedial Options Workshop held in 2009 (SRK 2009). Costs of the selected remedial measures were estimated taking into account up-front capital costs as well as any ongoing operating or maintenance costs incurred in perpetuity (or as long as the measure is implemented). Many cost estimates were developed in such a way that they could be scaled to allow for easy estimation of additional activities not specifically included in the costing report.

Within this study, costs of implementing 48 different remedial activities were estimated; considered activities ranged in cost from $75,000 (for plugging flowing boreholes) to $55,000,000 (for a reverse osmosis water treatment plant at the outlet of Greer Lake).

1.4.3 Beaverlodge Remedial Options Workshop, 2012

A 2-day Beaverlodge Remedial Options Workshop was held in Saskatoon in April of 2012 as a follow up to a Remedial Options Workshop held in 2009 (SRK 2009). Forty six (46) participants attended the 2012 workshop; representatives were present from the local community, northern Saskatchewan Environment Quality Committee, regulatory agencies, consulting companies, and industry. Remedial options selected for discussion during the 2012 workshop were drawn from both the outcomes of the 2009 workshop and findings from the Beaverlodge QSM. In addition to pre-selected remedial options, at the end of day 1 of the workshop participants were asked to propose additional remedial scenarios for discussion; the predicted costs and expected change to environmental conditions based on these suggested scenarios were determined that evening so that the additional scenarios could be assessed as a group during day 2 of the workshop.

For each remedial scenario assessed, estimated costs were presented along with water quality predictions and estimated impact on risk to ecological and human health. These costs were drawn from the Beaverlodge Costing Study while the water quality and human health/ecological risk predictions were generated using the Beaverlodge QSM. For each scenario assessed an open discussion of pros and cons took place followed by evaluation of the scenario by stakeholders in breakout groups. Overall, the workshop participants assessed 14 remedial scenarios consisting of 21 individual remedial activities.

Some general conclusions from the workshop include:

- The “do nothing” option was not acceptable to any participant groups.
- Minor activities with measureable benefit and reasonable cost were identified (i.e., plugging boreholes, minor stream diversion, and gamma attenuation).
- Some options identified have uncertainty regarding expected benefit and technical feasibility (i.e., passive treatment of Lower Ace Creek seeps, water treatment, inducing algal blooms in Beaverlodge Lake).
- Large scale remedial options deemed to be too expensive in relation to the expected benefit (i.e., large scale stream diversion, sediment and waste rock covers, and water treatment).

2.0 ASSESSMENT OF REMEDIAL ACTIVITIES

In the Beaverlodge study area, numerous remedial activities were assessed to determine their potential change to environmental conditions and associated risk. The selection of remedial activities for study and subsequent assessment for inclusion in the Beaverlodge remedial plan is detailed in this chapter.

2.1 ASSESSMENT APPROACH

Remedial measures were selected for assessment and then evaluated based on a number of criteria. The methodology used to identify and examine potential remedial activities is discussed in Section 2.1.1 while the criteria used to evaluate each measure for inclusion in the Beaverlodge path forward plan are outlined in Section 2.1.2. It should be noted that during previous work combinations of options were considered and presented to stakeholders; however, for clarity within this report the benefit of each option was assessed individually.

2.1.1 Prediction of Environmental Conditions and Site Risks

Sections 2.2 through 2.7 step through the Beaverlodge study area, site by site, identifying risks to humans and wildlife accessing each property, selecting remedial measures for examination based on identified risks, assessing selected remedial activities, and then determining the suitability for inclusion of the activity in the Beaverlodge path forward plan.

A screening level risk assessment was performed by Cameco in 2010 based on the International Organization for Standardization (ISO) Standard ISO 31000 *Risk Management – Principles and Guidelines*; the goal of this assessment was to characterize, at a preliminary level, the current nature of the risks associated with the decommissioned properties (Cameco 2010b). During development of the Beaverlodge QSM, the screening level assessment was revisited and based on the more-detailed risk assessment encompassed within the QSM as well as with further information which was collected since the assessment was first completed. Risks posed by each site aspect were predicted by first estimating the likelihood and consequence of the associated event and then converting these values to overall risk using the matrix shown in Figure 2.1-1. Updated outcomes of this assessment are presented in tabular format at the beginning of each site section.

Figure 2.1-1 Cameco Risk Evaluation Matrix

			Consequence				
			Insignificant 1	Minor 2	Moderate 4	Major 8	Catastrophic 12
Likelihood	5	Very Likely	5	10	20	40	60
	4	Quite Likely	4	8	16	32	48
	3	Somewhat Likely	3	6	12	24	36
	2	Unlikely	2	4	8	16	24
	1	Very Unlikely	1	2	4	8	12

Selected remedial measures for each site were then studied using outcomes of the Beaverlodge QSM (SENES 2012a), the Beaverlodge Costing Study (SENES & SRK 2012) as well as the 2012 Beaverlodge Remedial Options Workshop (ASKI, SENES & SRK 2012).

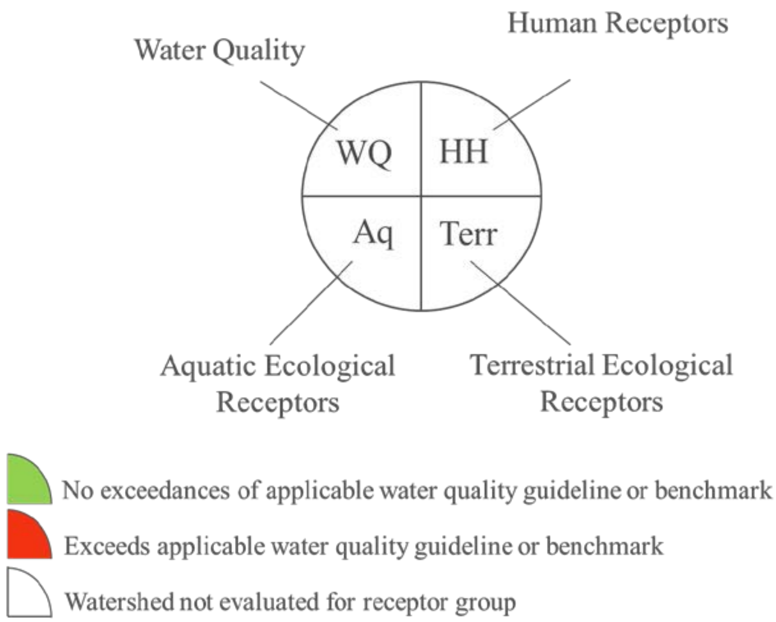
For remedial measures which may affect water quality within the Beaverlodge study area, water quality predictions were generated using the Beaverlodge QSM and are presented for a number of Beaverlodge study area water bodies. On these graphs the base case water quality predictions with no remedial measures and the predicted water quality assuming implementation of the assessed remedial measure in the year 2015 are presented along with the Saskatchewan surface water quality guidelines for comparison.

Water quality predictions generated and shown within this chapter focus on the key constituents of concern within the Beaverlodge study area, namely radium-226, selenium and uranium. These three elements were identified through a screening process which also compared arsenic, copper, iron, nickel, lead, zinc, lead-210, polonium-210 and total dissolved solids to applicable guidelines.

Water and sediment quality predictions were also used within a risk assessment framework to estimate the potential exposure of human and ecological receptors expected to frequent each study area to these constituents of concern. The estimated exposure values were converted into Screening Index (SI) values to determine if potential risks to receptors frequenting the Beaverlodge study area exist. If the calculated SI value is in exceedance of the applicable benchmark, there is the potential for risk to the human or ecological receptor in question.

In order to provide a quick way to compare the environmental conditions throughout time with and without remediation, the water quality exceedances as well as any predicted risk to assessed human and ecological receptors are summarized with a series of 'pies' or 'snapshots' for the years 2010 (prior to implementing the remedial measure), 2040 and 2100 using the formatting illustrated in Figure 2.1-2. Water column exceedances are indicated in the upper left quadrant of the 'pie', predicted risks to human receptors are shown in the upper right quadrant, while potential risks to assessed aquatic and terrestrial receptors are indicated in the lower left and right quadrants, respectively. The colour of the quadrant indicates the presence of exceedances: green indicates that there are no predicted exceedances, red indicates that exceedances are predicted, and white background indicates that that receptor group was not evaluated within that sub-watershed.

Figure 2.1-2 Environmental Condition Snapshot Legend



For further information on the contaminant dispersion modeling or human health and ecological risk assessment used to generate these predictions please refer to the Beaverlodge QSM report (SENES 2012a).

2.1.2 Evaluation Criteria

Each selected remedial activity was studied as outlined in Section 2.1.2. A number of criteria were then used to aid in determining if the predicted benefits justify the expected costs and, ultimately, if the remedial activity should be included in the Beaverlodge remedial path forward plan. These criteria were as follows:

- Expected benefits (i.e., risk reduction)
    - Benefits may include improved aquatic environment, implementation of activities considered to be good engineering practice and/or improved safety to humans and wildlife on the site
- Predicted costs
- Stakeholder opinion
    - Along with regular site tours and public meetings, the social acceptability of the remedial options was determined through remedial options workshops, which were held in 2009 and 2012 and conducted by third-party facilitators.
    - At the 2012 workshop, stakeholders were provided estimates on the costs, benefits and potential risks associated with a series of potential remedial options, and then were asked to provide their feedback on the reasonability of each option.
- Level of uncertainty regarding technical feasibility or costs
- Amount of long term maintenance activities / operation costs expected
- Regulatory requirements

2.2 DUBYNA MINE SITE

The Dubyna Mine site is located within the Ace Creek Watershed. The main water body in the Dubyna area is Dubyna Lake which receives water from upstream Schmoo Lake. Water exiting Dubyna Lake flows south to Ace Creek before entering Ace Lake. The Dubyna Mine area is shown in Figure 2.2-1.

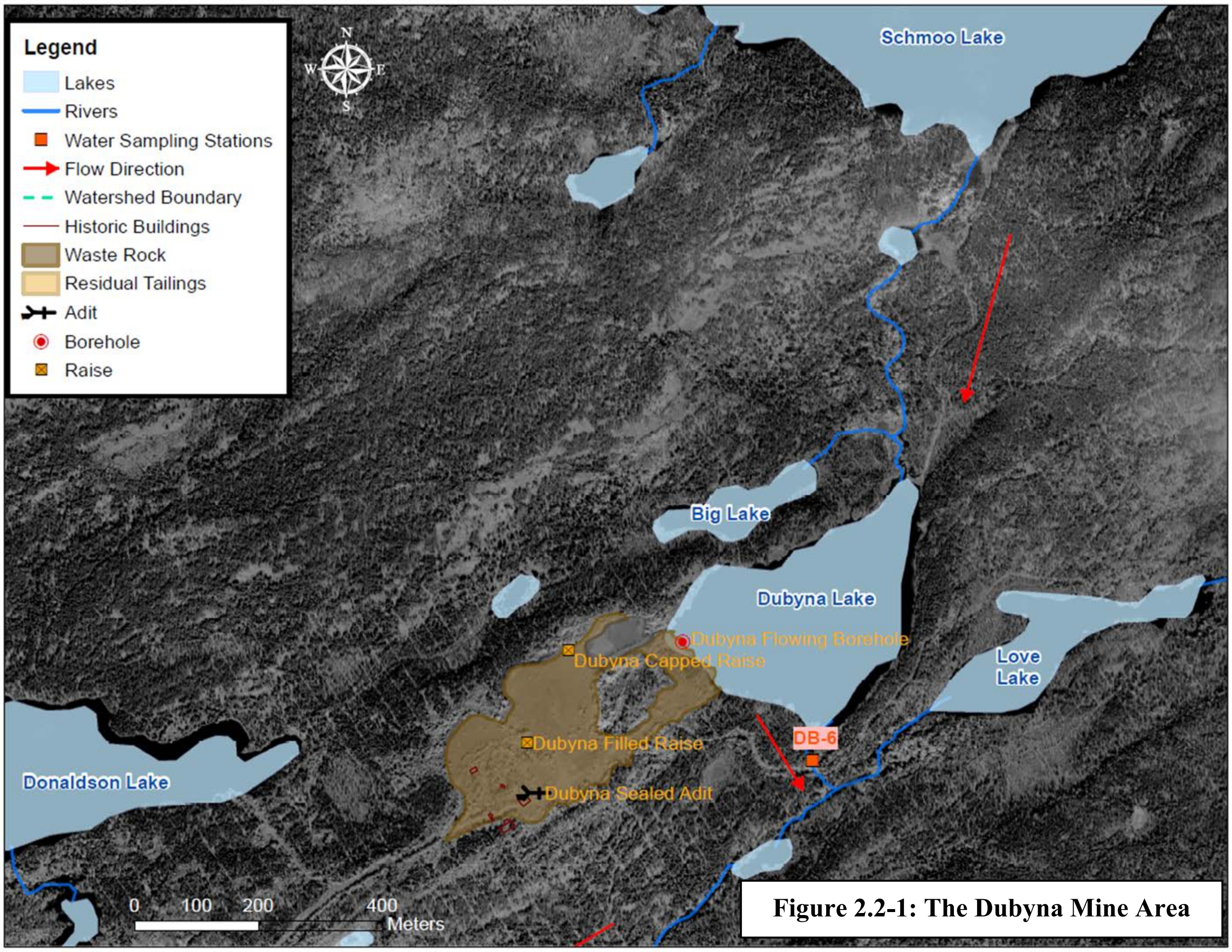


Figure 2.2-1: The Dubyna Mine Area

2.2.1 Dubyna Site Features

At the Dubyna mine site, waste rock from an open pit and from underground workings was placed in a small drainage area situated to the west of Dubyna Lake. Drainage from the pile flows into Dubyna Lake, as does the outflow from one or more drill holes located within and/or upgradient of the lake. Field investigations have identified several potential flowing drill holes in the shallow waters along the west shoreline of Dubyna Lake.

During operations (from 1978 to 1982) minewater at Dubyna was treated underground for radium removal and water treatment sludge was reportedly disposed in the underground mine workings. Water quality in Dubyna Lake is influenced by the freshwater inflow from Schmoo Lake, which drains a small sub-watershed area. The effects of drainage from the Dubyna mine site on the downstream water quality are monitored routinely at station DB-6 on Dubyna Creek (see Figure 2.2-1).

2.2.2 Dubyna Assessment of Potential Risks

In order to select remedial measures, the potential risks that various features within the Dubyna site may pose to the environment and members of the public accessing the site were assessed. Aspects examined included mining geotechnical; surface water; contaminated substrate; air, radon and gamma; terrestrial and aquatic vegetation; and risk communication. When determining a relative risk rating for each site element likelihood of the event occurring as well as the consequence of that event were considered. The resulting relative risk estimates for the Dubyna Mine site are shown in Table 2.2-1.

Table 2.2-1 Summary of Estimated Risks, Dubyna Area

Aspect	Specific Location	Site Element	Current Risk Registry		Risk Endpoint		References
			Event	Effect	Environment Risk	Public Health and Safety Risk	
Mining Geotechnical	**Dubyna Site**	**Crown Pillar**	Pillar failure (collapse)	Formation of sinkholes creating a falling hazard for wildlife and human	**L**	**ML**	Screening Level Risk Assessment, Cameco 2010b.
		Waste Rock Pile	Slope instability and failure	Falling hazard for wildlife and human	**L**	**L**	Departure With Dignity: Decommissioning of the Beaverlodge Mine/Mill. MacLaren Plansearch 1987.
		Pit Walls	Walls failure	Hazardous situation for wildlife and human	**L**	**L**	Beaverlodge Project: Pit Slope Stability Inspection Report, SRK 2010
			Falling Hazard	Falling event for wildlife and human	**L**	**ML**	Screening Level Risk Assessment, Cameco 2010b.
		Demolition Material	Erosion causing exposure of material	Safety concern, e.g. falling hazard	**L**	**ML**	Screening Level Risk Assessment, Cameco 2010b.
		Sealed Openings to Surface	Cap fails (2 vertical opening)	Formation of opening (vertical hole) to underground workings creating a falling hazard for wildlife and human	**M**	**M**	Departure With Dignity: Decommissioning of the Beaverlodge Mine/Mill. MacLaren Plansearch 1987.
			Portal (1 portal filled with waste rock)	Open access to workings	**L**	**ML**	Departure With Dignity: Decommissioning of the Beaverlodge Mine/Mill. MacLaren Plansearch 1987.
Surface Water (incl. Flowing Drillholes)	**Dubyna Site**	**Waste Rock Pile**	Surface runoff and precipitation infiltration through the waste rock into Dubyna Lake	Impact on Dubyna Lake water quality	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a.
		Flowing Drill Holes	Seepage to surface water	Impact on Dubyna Lake water quality	**M**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009. Results of Investigations into the Remediation of Flowing Boreholes. Golder 2010.
		Demolition Material	Erosion of demolition material and discharge to Dubyna Lake	Impact on Dubyna Lake water quality	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
	Dubyna Lake	**Dubyna Lake water**	Discharge to downstream waters	Impact on Upper Ace Creek water quality	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009. Results of Field Investigations in the Areas of the Decommissioned Fay-Verna, Hab and Dubyna Mines, Golder 2010.
				Impact on Ace Lake water quality	**L**	**L**	
Contaminated Substrate	**Dubyna Lake**	**Substrate**	Accumulation of contaminants in sediment	Impact on Dubyna Lake water quality	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009. Deep Basin Sediment Study. CanNorth 2012. Aquatic Macrophyte Sampling Program. CanNorth 2011a.
Air, Radon and Gamma	**Dubyna Site**	**Waste Rock Pile**	Dusting of waste rock and release of airborne contaminants	Inhalation exposure for wildlife and human	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
			Radon release from exposed rock	Prolonged radon exposure for wildlife and human	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
			Gamma exposure from waste rock	Prolonged gamma exposure for wildlife and human	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
			Gamma exposure from pit walls	Prolonged gamma exposure for wildlife and human	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
Terrestrial and Aquatic Vegetation	**Dubyna Site**	**Terrestrial Vegetation**	Release of COPC to air	Potential uptake of contaminants in vegetation and impact to VECs	**L**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Country Foods Survey. SENES 2012b. Draft.
		Aquatic Vegetation	Leaching of COPC to water	Potential uptake of contaminants in vegetation and impact to VECs	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Aquatic Macrophyte Sampling Program. CanNorth 2011a. Country Foods Survey. SENES 2012b. Draft.
Risk Communication	**Dubyna Site**	**-**	Level of awareness of site risk	Public perception and potential safety risk	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.

As can be seen within Table 2.2-1, potential events which were estimated to pose the greatest risk to the environment and public accessing the site include failure of caps on vertical mine openings and seepage of water through flowing drill holes to Dubyna Lake; remedial measures examined within the following section are focused on these features and potential events. It should be noted that none of the risks from this property are ranked ‘high’.

2.2.3 Dubyna Assessment of Remedial Activities

Potential remedial measures considered based on identified risks within the Dubyna Mine site and/or to meet the standard of good engineering practice:

- Divert Schmoo Lake outflow around Dubyna Lake
- Place cover on waste rock pile
- Plug boreholes
- Treat water at the outlet of Dubyna Lake
- Replace caps on vertical openings
- Plug non-flowing boreholes

Each of these activities will be discussed in the following sections.

2.2.3.1 Schmoo Lake Outflow Diversion

The stream diversion considered for the Dubyna Mine site involves activities to reroute the Schmoo Lake discharge through Love Lake to Ace Creek, thereby isolating Dubyna Lake. Conceptual design of this diversion is discussed in SRK (2011). The design involves drilling and blasting to construct an unlined channel 2 m wide to redirect the flow.

Potential change to environmental conditions based on this stream diversion was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes. Assumptions which were made in order to predict the effects of this activity are:

- It was assumed that this diversion is able to successfully eliminate 100% of the Schmoo Lake outflow from entering Dubyna Lake. It was also assumed that none of the water flowing through Schmoo Creek accesses the underground mine workings; hence, this activity was considered to have no effect on flow from drill holes connected to the underground mine workings.

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 43% from $2.0x10^4$ kBq/yr to $1.1x10^4$ kBq/yr, a reduction in uranium load of 51% from 96 kg/yr to 47 kg/yr and a reduction in selenium load of 78% from 0.06 to 0.01 kg/yr to the downstream environment.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.2-2 and 2.2-3. As can be seen, there is a significant increase in radium-226 and uranium levels in the water column of Dubyna Lake due to this activity. This is due to the fact that without the fresh water influx, constituents within Dubyna Lake are left to concentrate within the water column and sediments of the lake and not flow downstream to Ace Lake. The purpose of this diversion would be to prevent clean water originating upstream of the Dubyna Mine site from becoming contaminated. The negative aspect to this remedial measure is that it results in a much more contaminated Dubyna Lake. The benefit seen downstream in Ace Lake is that uranium levels in the water column are predicted to drop below the applicable guideline approximately 15 years earlier than without the diversion. It should be noted that water quality in Ace Lake without any remedial activities is predicted to be below the applicable guidelines with the exception of uranium in the first few years. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.2-4 and 2.2-5 for Dubyna Lake and Ace Lake as compared to the base case, with no remediation. As can be seen, implementation of this diversion causes increased risk to terrestrial receptors in Dubyna Lake while it has no effect on exceedances predicted in Ace Lake. Risks to receptors utilizing Ace Lake are predicted to be below the applicable SI benchmarks with and without this stream diversion.

Costs of this stream diversion were estimated by SRK (2011) and further discussed in SENES & SRK (2012) to be approximately $3.2 million CAD including the net present value (NPV) of a $10,000 CAD per year maintenance cost for the diversion channel.

Figure 2.2-2 Dubyna Lake Water Quality Predictions (Divert Schmoo Lake Outflow)

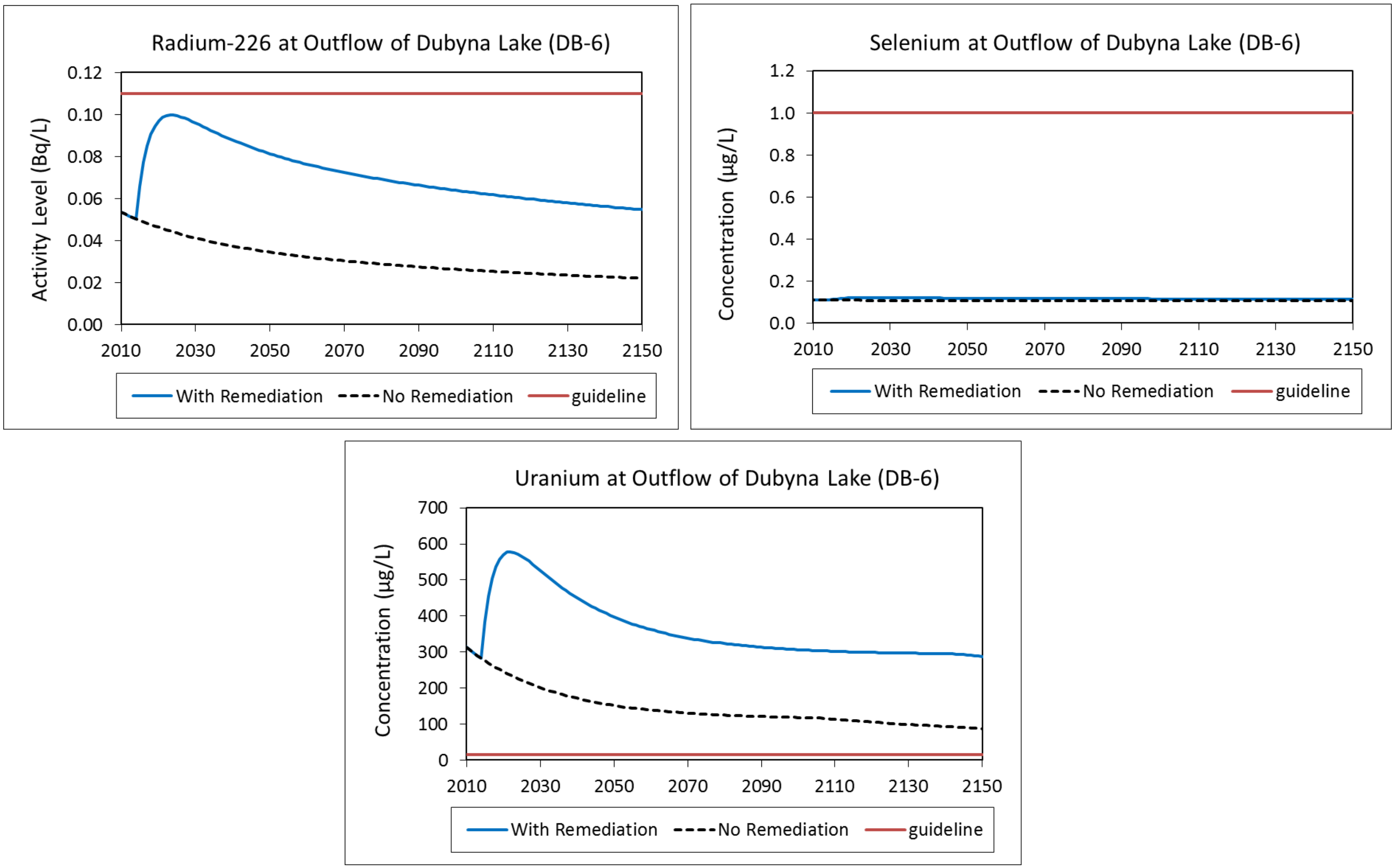


Figure 2.2-3 Ace Lake Water Quality Predictions (Divert Schmoo Lake Outflow)

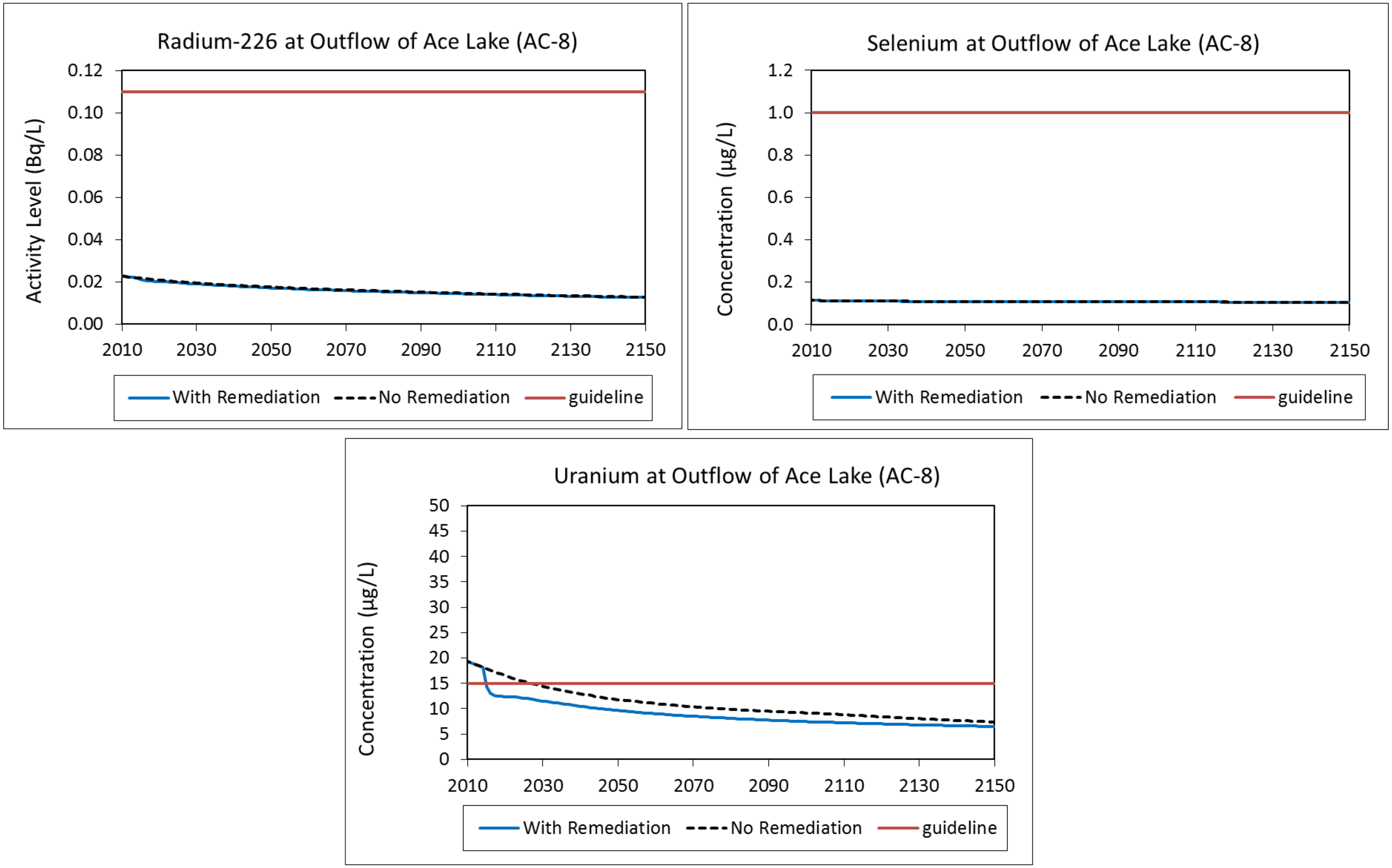


Figure 2.2-4 Summary of Outcomes in Dubyna Lake (Divert Schmoo Lake Outflow)

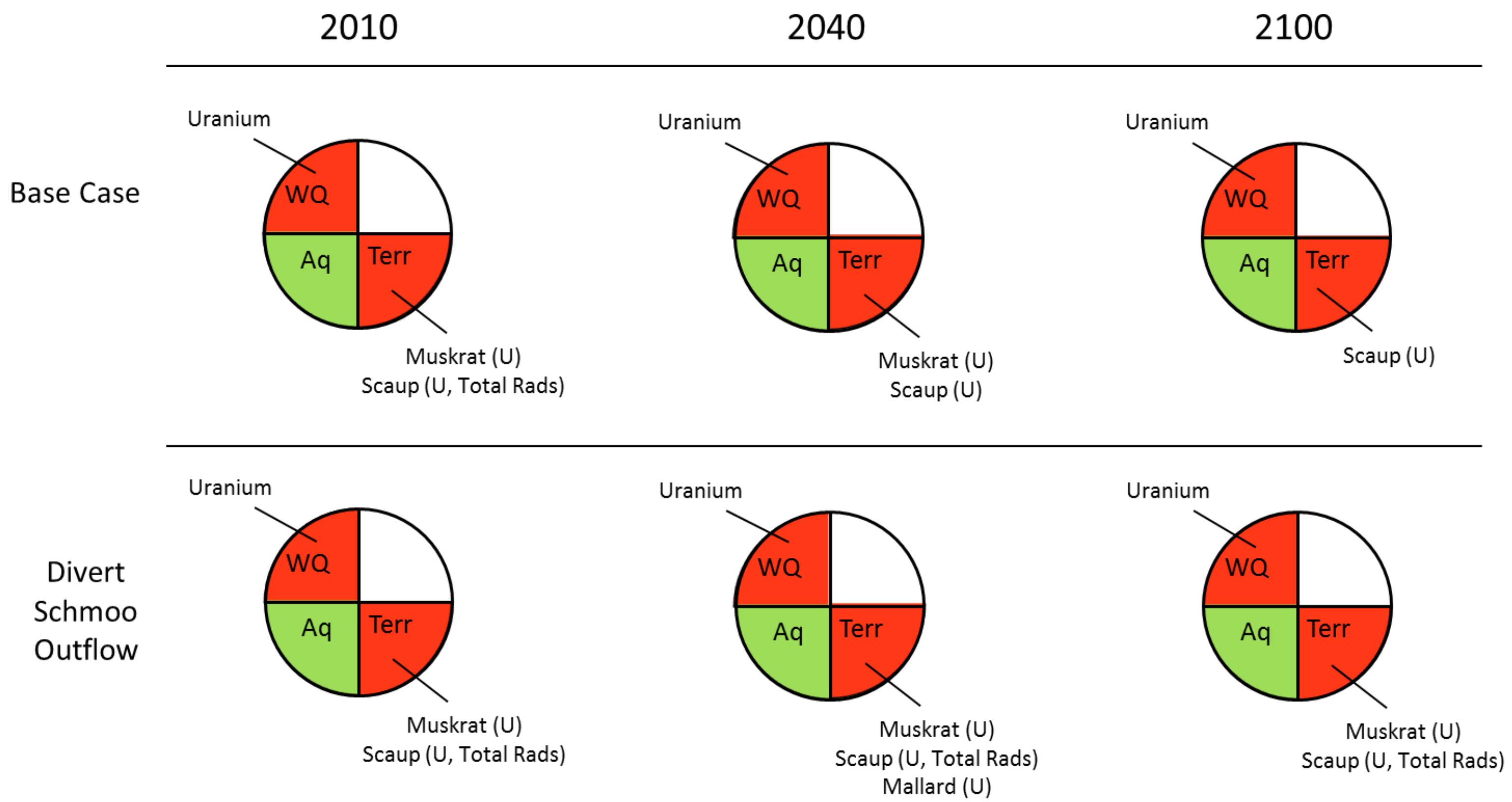
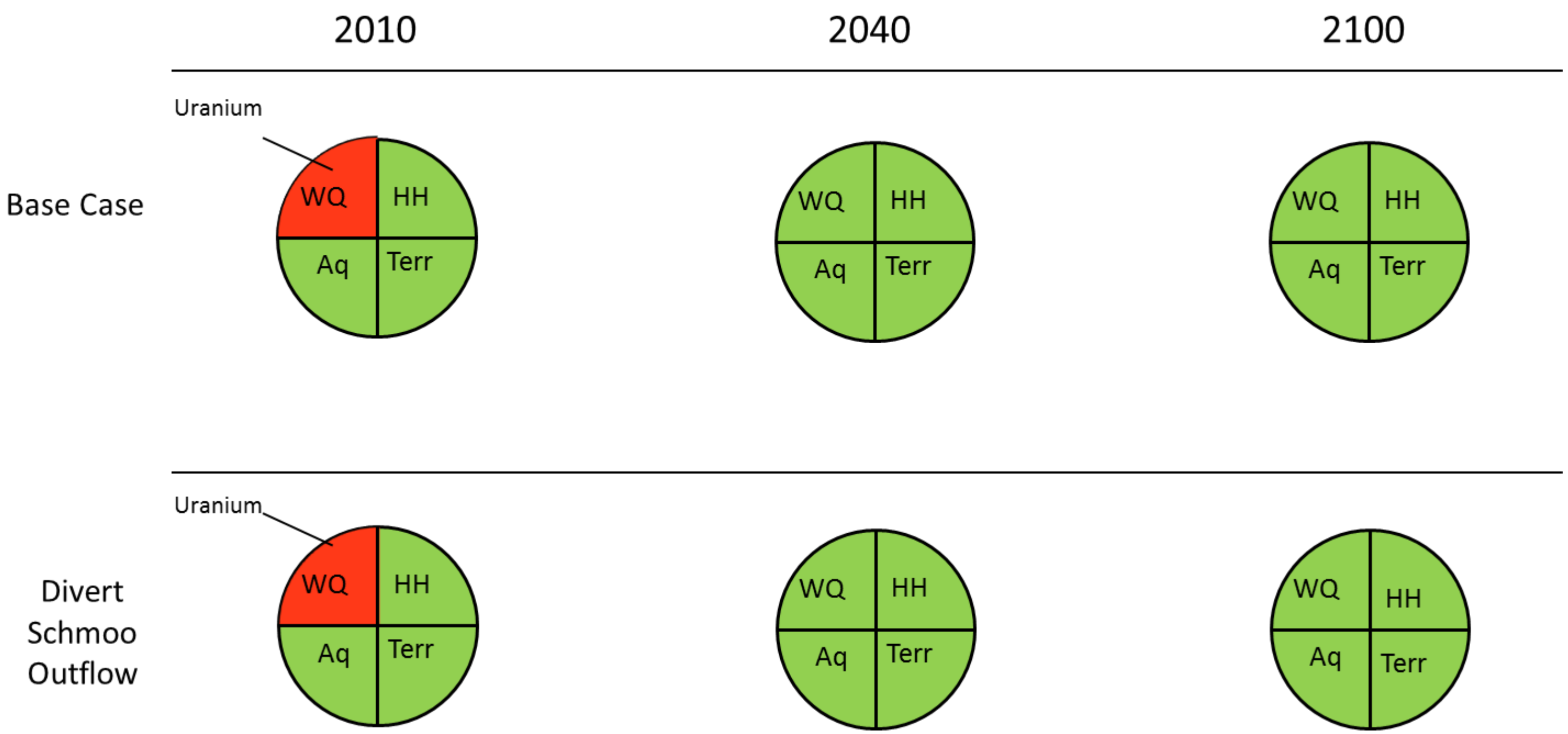


Figure 2.2-5 Summary of Outcomes in Ace Lake (Divert Schmoo Lake Outflow)



2.2.3.2 Cover Waste Rock Pile

This remedial measure involves installing a cover on the waste rock pile in the Dubyna Mine area. The pile was contoured during decommissioning activities in the 1980s, so it is expected that little additional grading would be required. Two options for covering the waste rock have been considered and would involve a cover with either a sand layer or a synthetic liner (such as HDPE) with sand layers placed above and below to protect the liner and encourage vegetation growth.

Potential change to environmental conditions based on covering the waste rock pile in the Dubyna area was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- As discussed in SENES & SRK (2012), with proper installation of a geo-synthetic liner such as the one discussed in this section, the percolation rates in the waste rock may be reduced to ~5% from 39%. The reduction in percolation through the waste rock pile is predicted to be much less with a sand cover, however, this option was assessed assuming the best case scenario.
- The annual precipitation rate for the region and base case percolation rate for the waste rock pile are discussed in SENES (2012) and were assumed to be 273 mm/a and 39%, respectively.

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 4% from 2.0×10^4 kBq/yr to 1.9×10^4 kBq/yr and a reduction in uranium load of 2% from 96 kg/yr to 94 kg/yr to the downstream environment.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.2-6 and 2.2-7. Almost no change to the predicted water quality is seen in Dubyna or Ace lakes as a result of this activity. It should be noted that water quality in Ace Lake without any remedial activities is predicted to be below the applicable guidelines with the exception of uranium in the first few years. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.2-8 and 2.2-9 for Dubyna and Ace lakes as compared to the base case, with no remediation. As can be seen, implementation of this remedial measure does not change the exceedances predicted in Dubyna or Ace lakes. Risks to receptors utilizing Ace Lake were predicted to be below the applicable SI benchmarks with and without the application of this cover. The results presented are for application of a geo-synthetic liner and if a sand cover is selected instead, the predicted benefit of this activity would be even less.

Costs of covering the Dubyna waste rock pile were estimated by SENES & SRK (2012) to be between approximately $3.0 and $5.9 million CAD for sand and geo-synthetic covers, respectively. These estimated costs include the NPV of a $10,000 CAD per year maintenance expense.

Figure 2.2-6 Dubyna Lake Water Quality Predictions (Cover Dubyna Waste Rock)

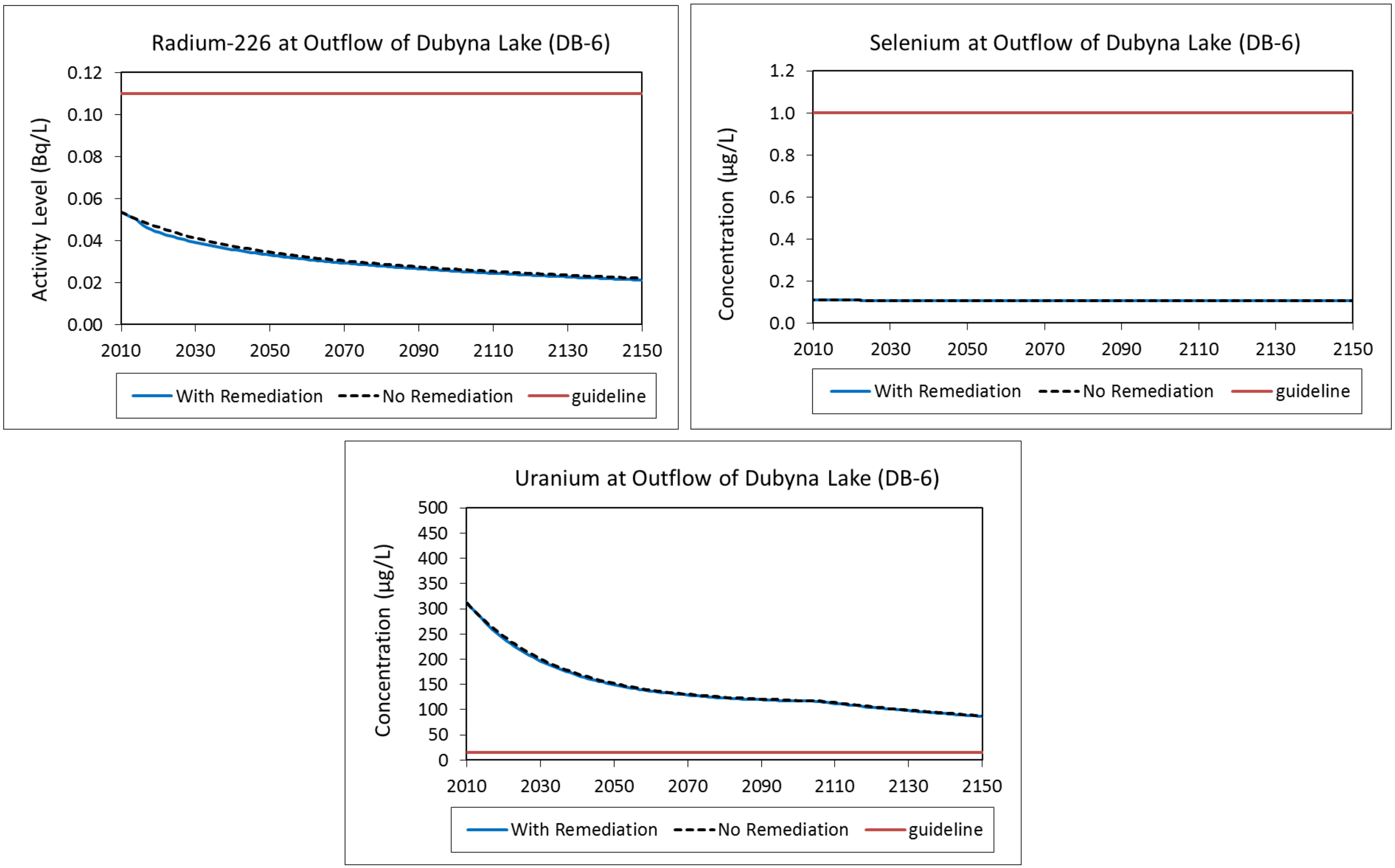


Figure 2.2-7 Ace Lake Water Quality Predictions (Cover Dubyna Waste Rock)

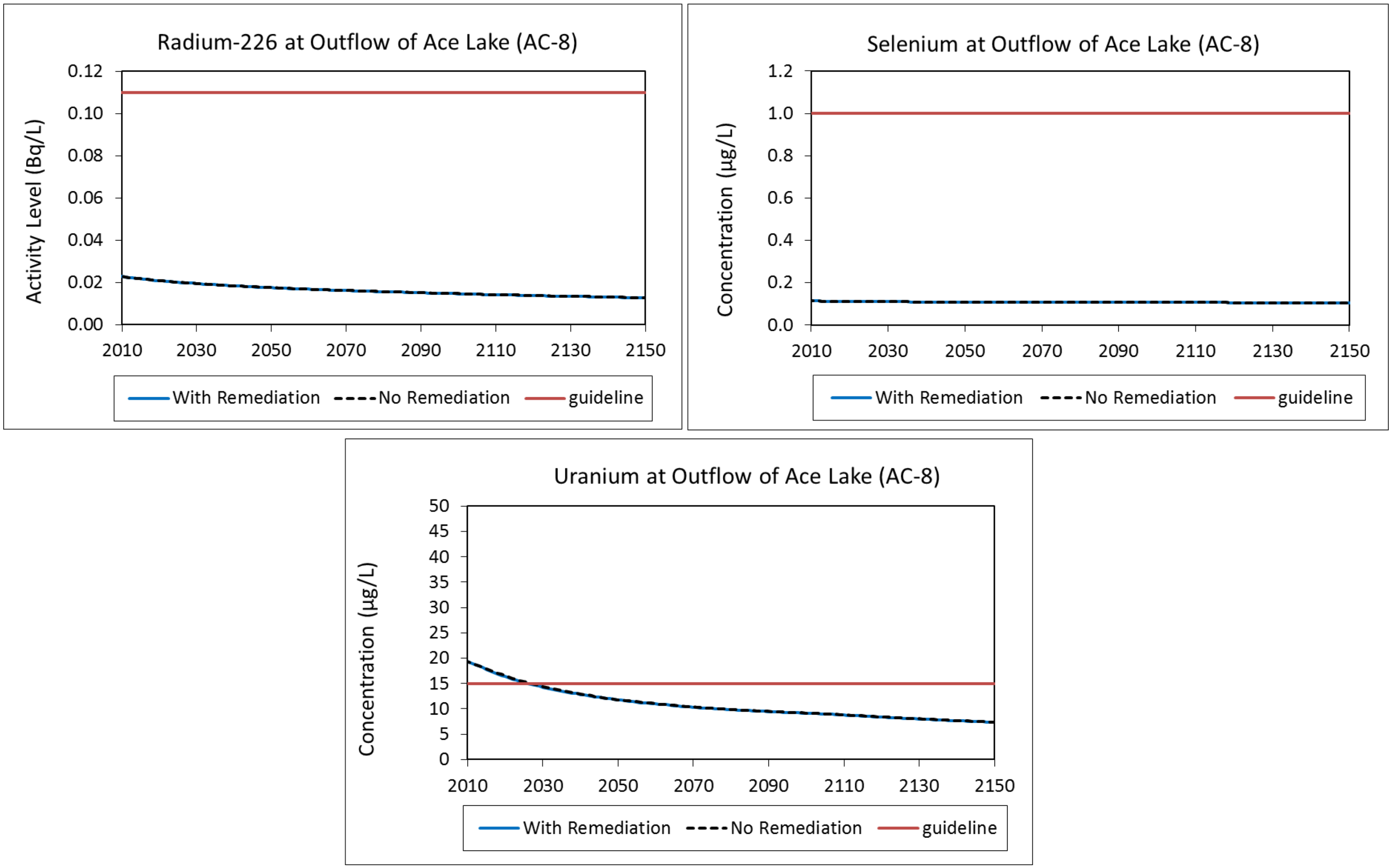


Figure 2.2-8 Summary of Outcomes in Dubyna Lake (Cover Dubyna Waste Rock)

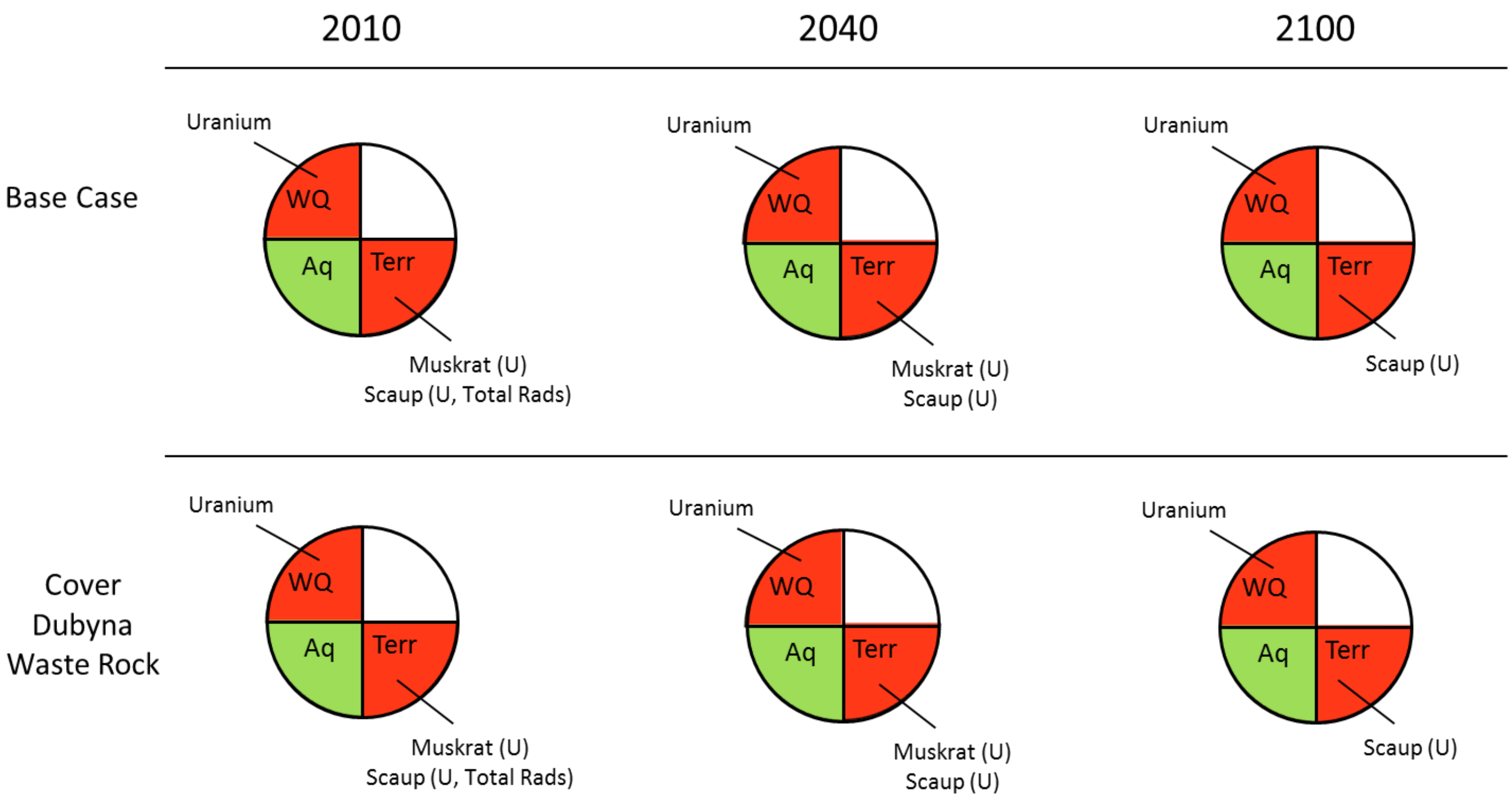
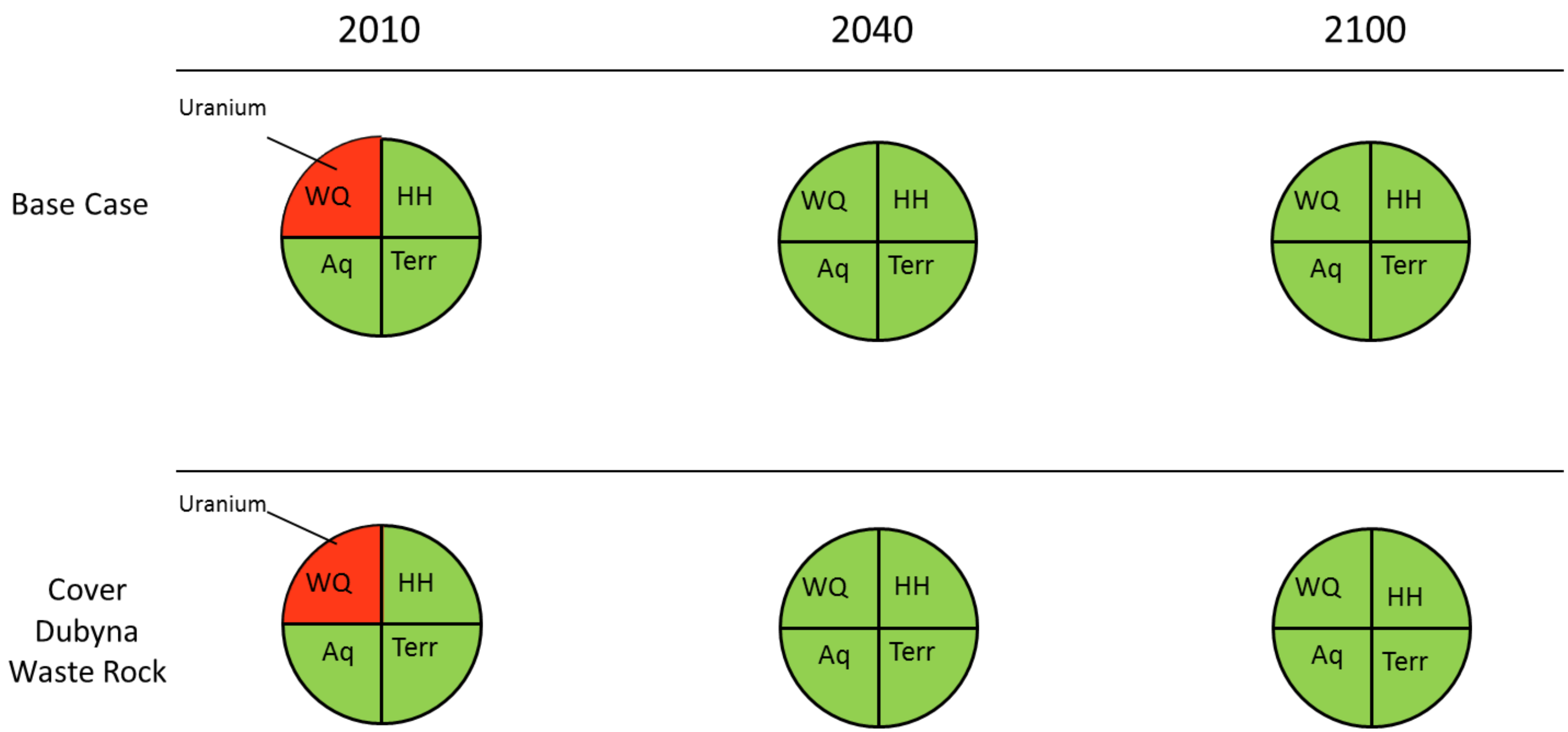


Figure 2.2-9 Summary of Outcomes in Ace Lake (Cover Dubyna Waste Rock)



2.2.3.3 Plug Identified Boreholes

This activity involves plugging boreholes identified along the shore of Dubyna Lake. There is uncertainty in the success of this activity as there may be additional unidentified flowing boreholes below the surface of Dubyna Lake and, in addition, it is possible that plugging the identified boreholes would cause flow from the underground mine to surface elsewhere within the area.

Potential change to environmental conditions based on plugging Dubyna area mine openings was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes, although this activity was completed in 2012.

Assumptions which were made in order to predict the effects of this remedial activity are:

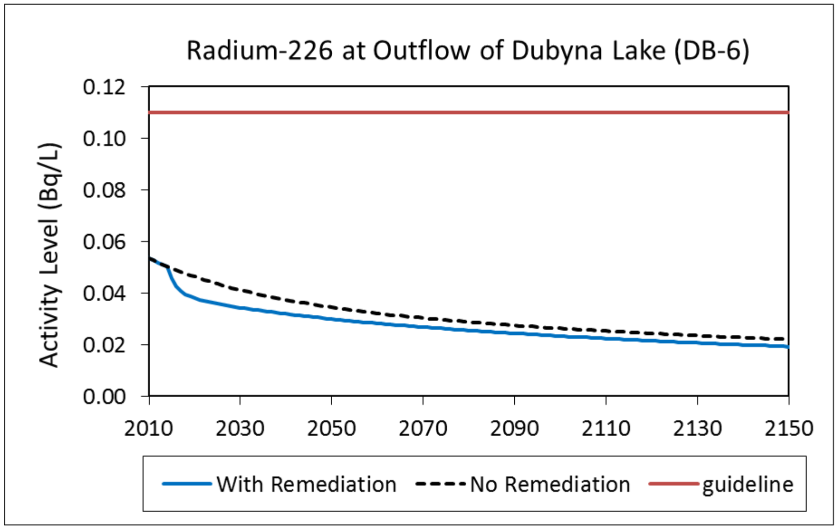
- As the uncertainty regarding the success of this activity is considered high, it was assumed, optimistically, that 80% of the flow could be located and stopped from entering the Dubyna sub-watershed.

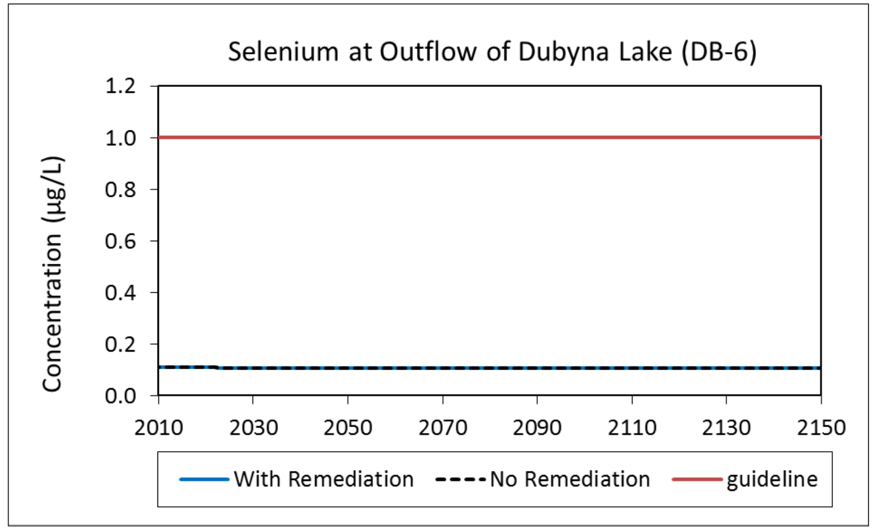
Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 15% from $2.0x10^4$ kBq/yr to $1.7x10^4$ kBq/yr and a reduction in uranium load of 38% from 96 kg/yr to 59 kg/yr to the downstream environment.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.2-10 and 2.2-11. While some reductions in uranium and radium-226 are seen in the immediate area (Dubyna Lake), only slight reduction in uranium levels in the downstream environment (Ace Lake) are predicted. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.2-12 and 2.2-13 for Dubyna Lake and Ace Lake as compared to the base case, with no remediation. As can be seen, implementation of this remedial activity does not change the exceedances predicted in Dubyna or Ace lakes. While uranium is predicted to be in exceedance of the provincial guideline during the first few decades, risk to assessed receptors in the Ace Lake area are predicted to be below the SI benchmarks for the entire modeled period both with and without this activity.

In 2011 and 2012, 3 flowing boreholes were identified and sealed for a cost of approximately $75,000 total. These holes were all relatively easily accessible and located in close proximity to one another. The cost of plugging any additional flowing boreholes discovered in the Dubyna Mine area is estimated to be $75,000 CAD per borehole.

Figure 2.2-10 Dubyna Lake Water Quality Predictions (Plug Dubyna Area Boreholes)





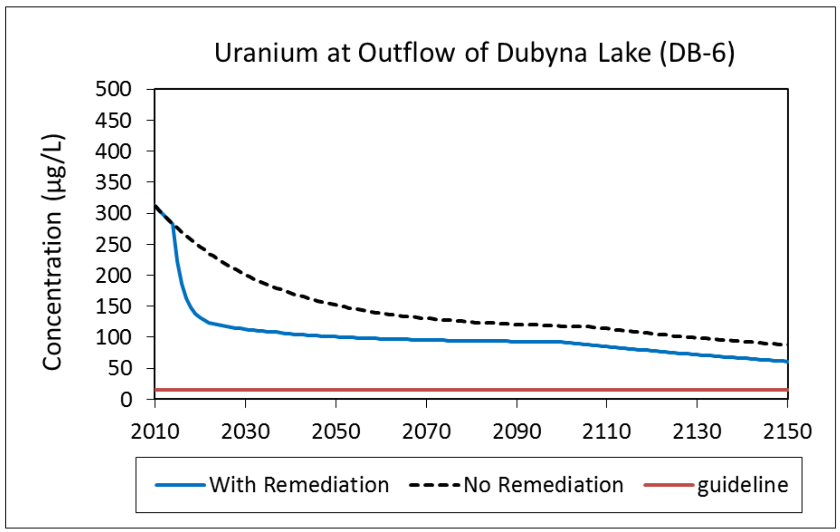


Figure 2.2-11 Ace Lake Water Quality Predictions (Plug Dubyna Area Boreholes)

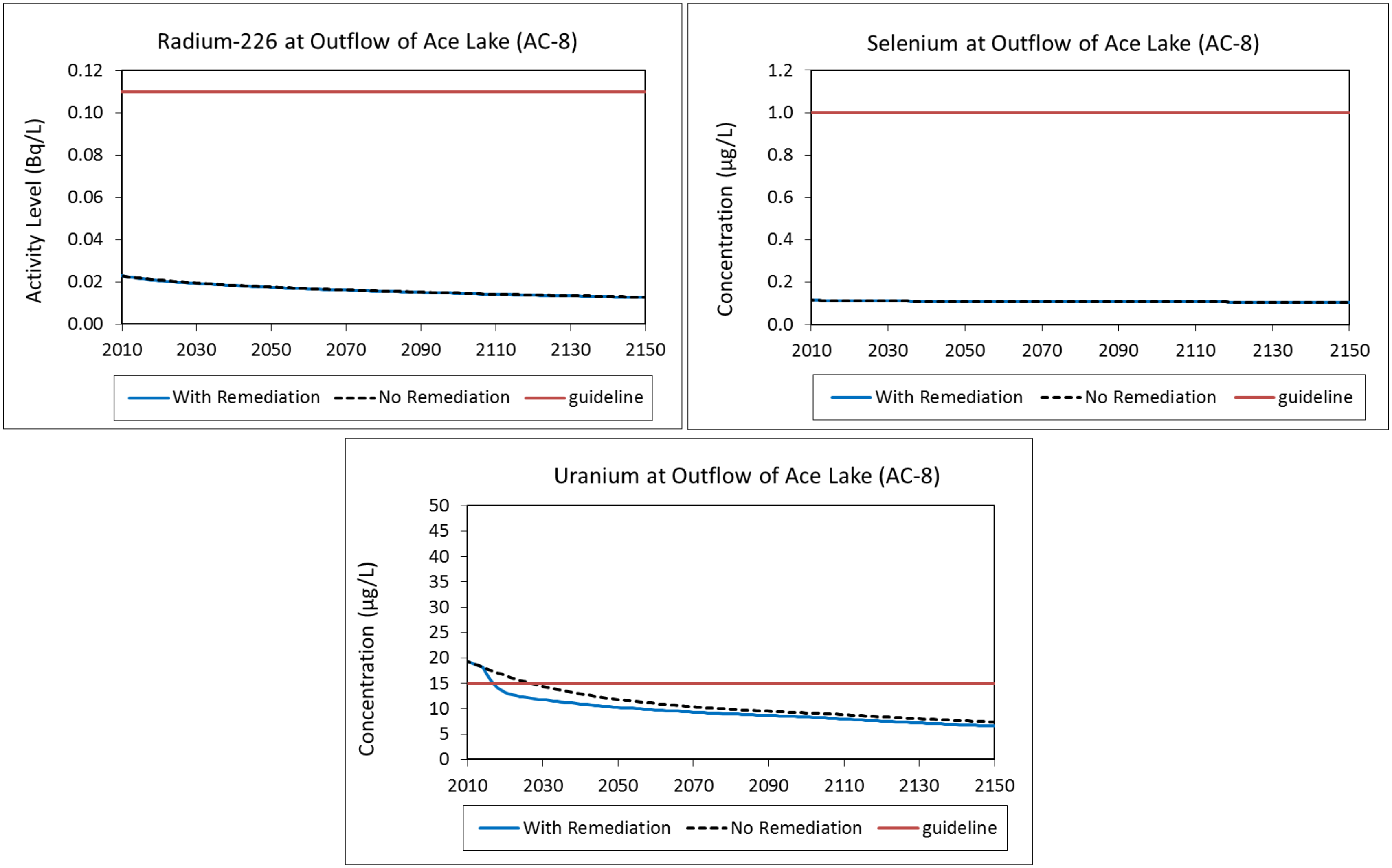


Figure 2.2-12 Summary of Outcomes in Dubyna Lake (Plug Dubyna Area Boreholes)

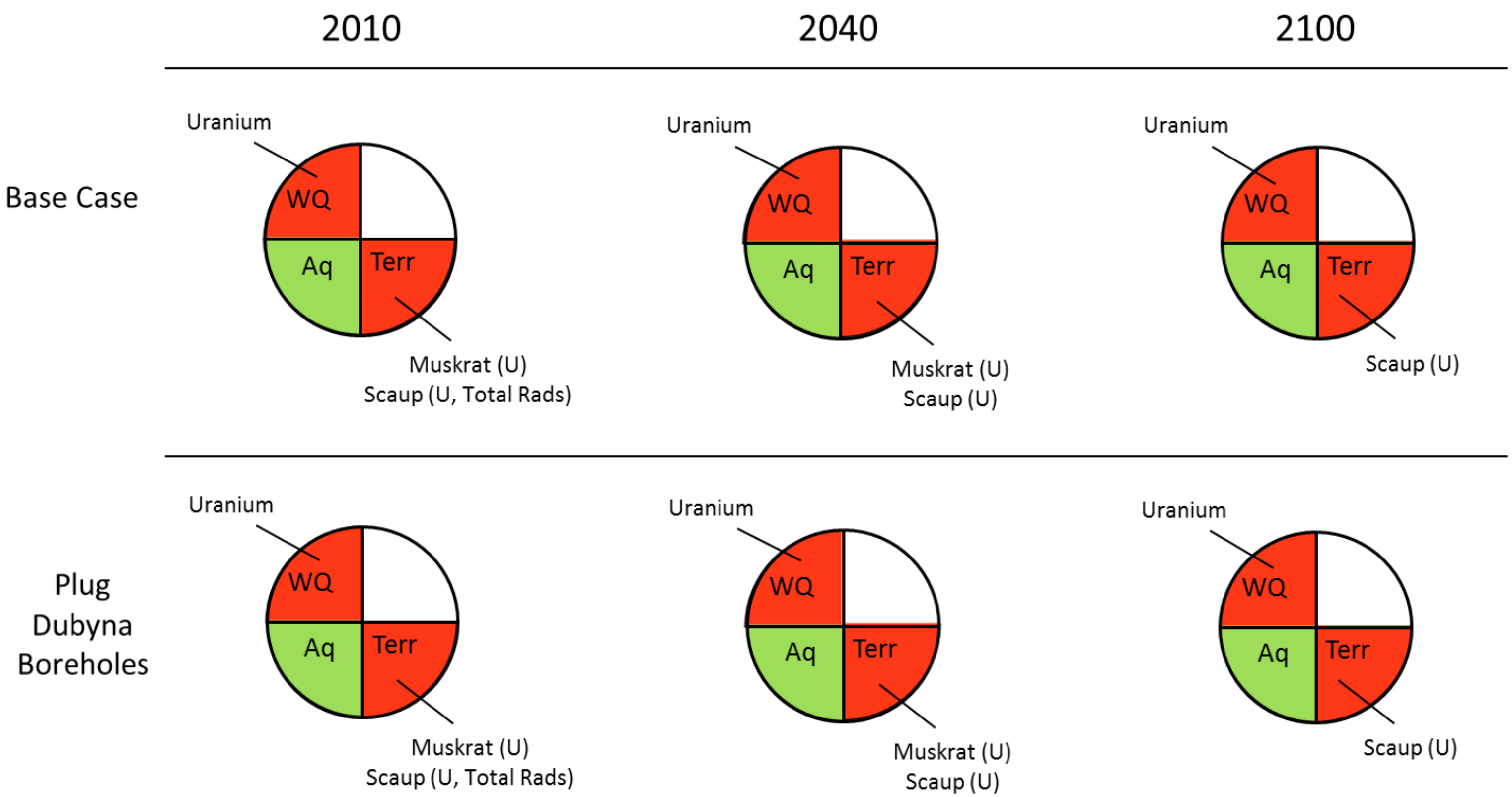
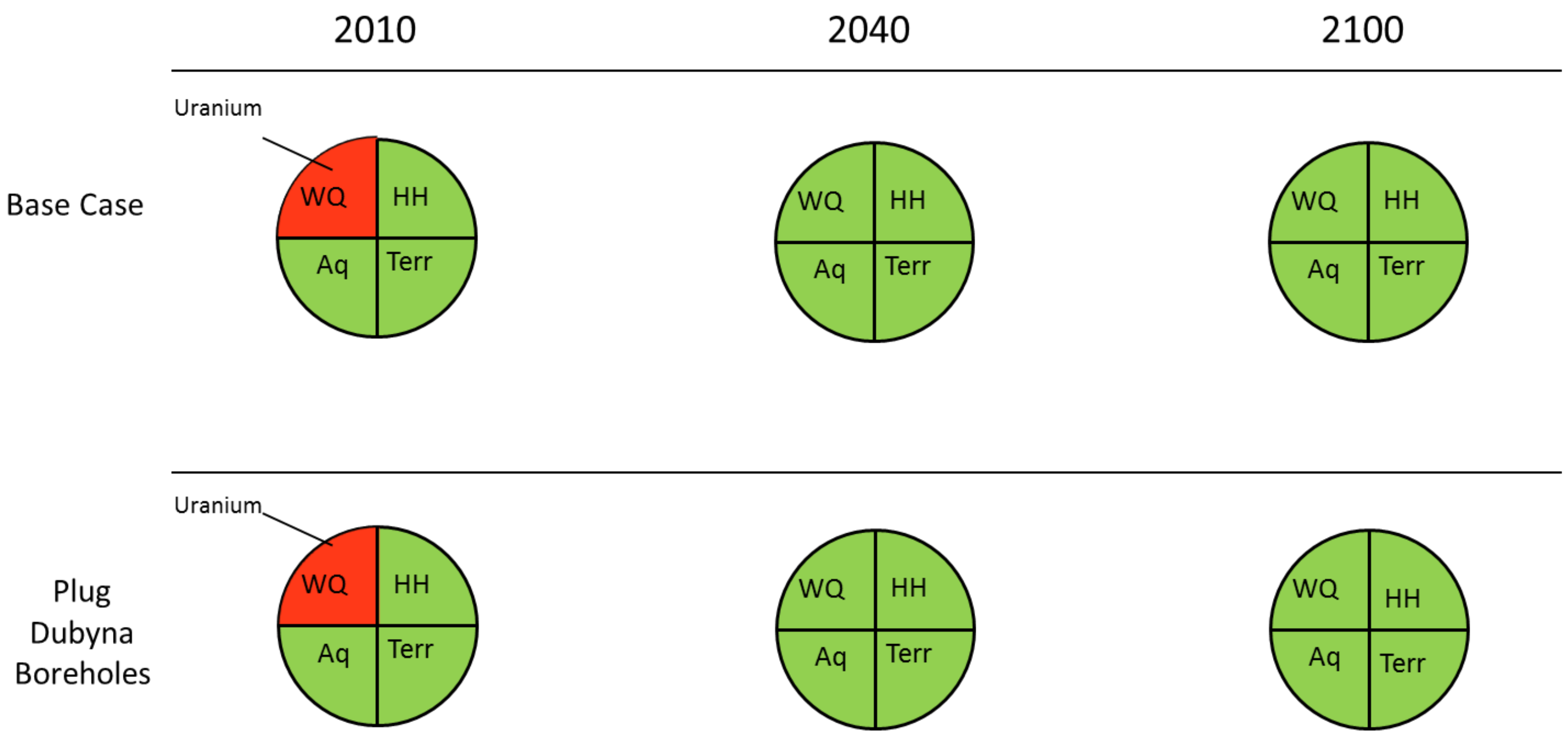


Figure 2.2-13 Summary of Outcomes in Ace Lake (Plug Dubyna Area Boreholes)



2.2.3.4 Water Treatment at the Outlet of Dubyna Lake

This activity involves installation of a water treatment system and associated dam structure at the outlet of Dubyna Lake. The Beaverlodge Costing Report (SENES & SRK 2012) looked at long-term removal of uranium only. Details of this system are provided in SENES & SRK (2012). The investigated system to handle uranium removal is an on-site ion exchange plant with an operating capacity of 515,000 m^3/yr over an operating period of 200 days/yr. The used resin generated by the operation of this system would be transported to one of Cameco's mills for uranium recovery on an annual basis. Disposal of the used resin may require additional regulatory approval.

Potential change to environmental conditions based on treating for uranium removal at the outlet of Dubyna Lake were assessed using the Beaverlodge QSM (SENES 2012a) assuming the installation of the treatment facilities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- Operating capacity of water treatment system is 515,000 m^3/yr, with additional water being discharged downstream untreated
- System able to achieve concentrations of:
    - Uranium: 10 μg/L

Over the first 50 years of implementation, these assumptions result in a predicted reduction in uranium load of 94% from 97 kg/yr to 6 kg/yr to the downstream environment. However, after 50 years of operation, either an additional investment will be required to maintain/replace the treatment facility or the load to the downstream environment will revert to the base case load from Dubyna Lake.

Predicted water quality in the downstream environment (Ace Lake) over the 2010-2150 period is shown in Figure 2.2-14. Water treatment at the outlet of Dubyna Lake is not expected to impact water quality within Dubyna Lake and therefore Dubyna Lake water quality is not shown. A moderate improvement in uranium levels in the water column of Ace Lake are predicted as a result of implementing this remedial activity, however, it should be noted that uranium levels within Ace Lake with no remedial measures are only predicted to be in exceedance of the applicable guideline in the first few decades. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figure 2.2-15 for Ace Lake as compared to the base case, with no remediation. As can be seen, implementation of this water treatment facility does not change the exceedances predicted in Ace Lake. While uranium is predicted to be in exceedance of the applicable guideline during the first few decades, risk to assessed receptors in the Ace Lake area are predicted to be below the SI benchmarks for the entire modeled period both with and without this activity.

It should be noted that this remediation activity involves perpetual maintenance of the water treatment system and associated dam structure at the outlet of Dubyna Lake.

Costs of installation as well as long-term operation and maintenance of the water treatment plant at the outlet of Dubyna Lake were estimated by SENES & SRK (2012) to be approximately $35.8 million CAD. These costs include the NPV of an annual operating and maintenance cost of $1.1 million CAD.

Figure 2.2-14 Ace Lake Water Quality Predictions (Water Treatment at Dubyna Lake Outlet)

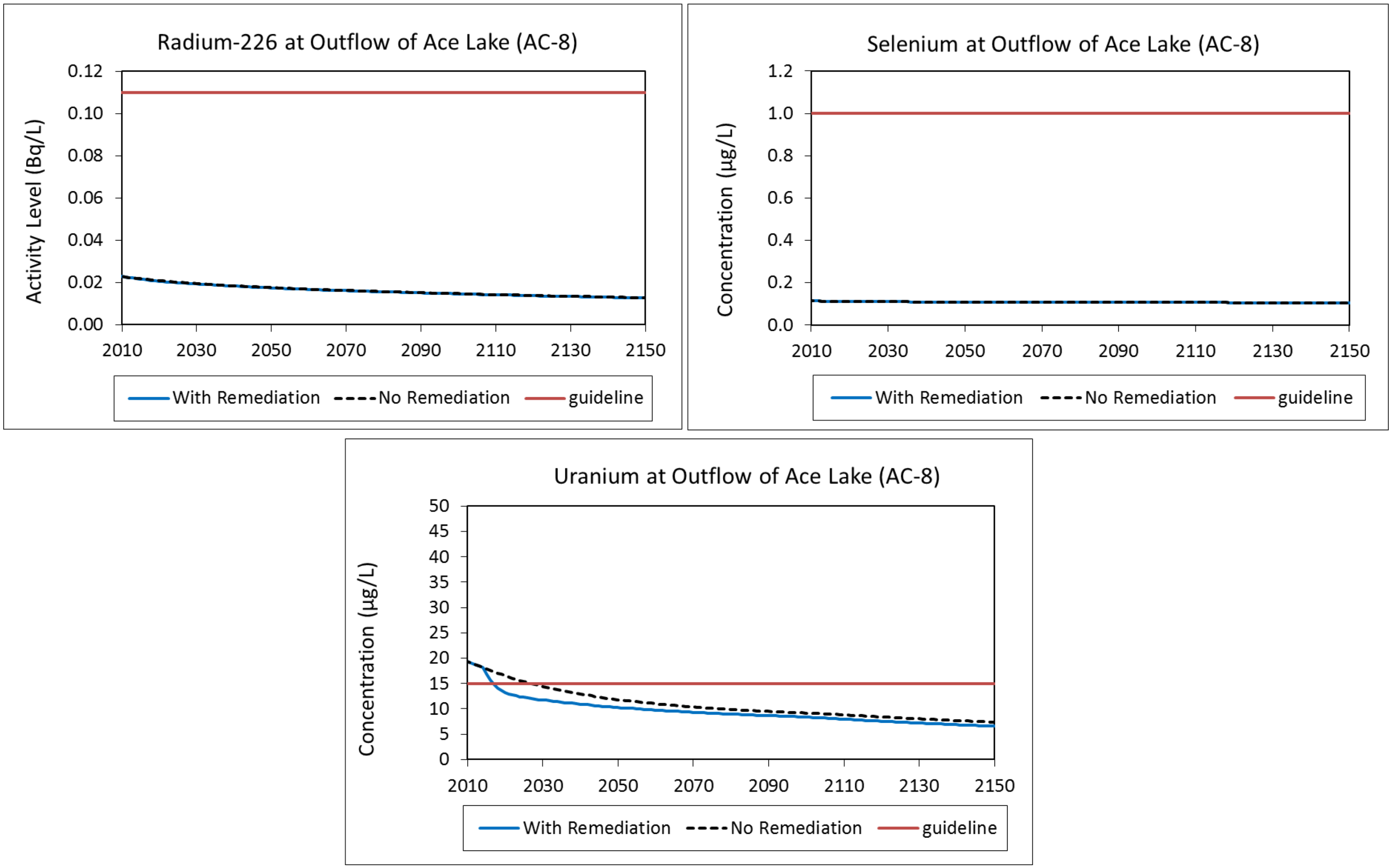
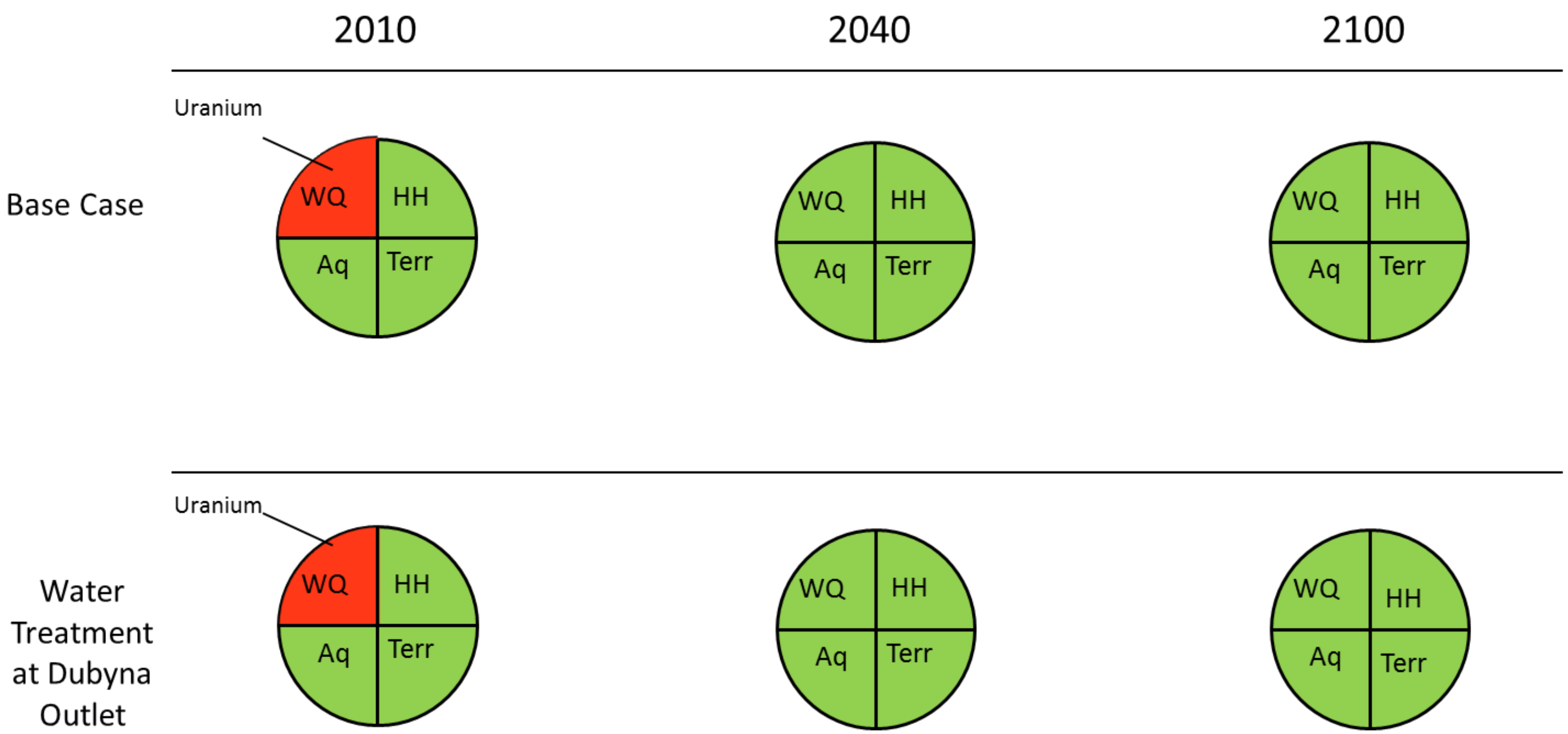


Figure 2.2-15 Summary of Outcomes in Ace Lake (Water Treatment at Dubyna Lake Outlet)



2.2.3.5 Replacement of Caps on Vertical Openings

This activity involves replacing the original concrete caps on all vertical mine openings in the Dubyna area with engineered caps, which may include concrete or stainless steel. The decommissioning documentation (MacLaren Plansearch 1987) identifies two openings in the Dubyna area; these openings are indicated in Figure 2.2-1.

It is not anticipated that this activity would result in any change to the immediate or downstream environments; however, it is included for discussion as it is considered to be good engineering practice and is expected to improve the long-term safety of the site for humans and wildlife frequenting the area. It is assumed that these engineered caps would require an assessment of condition after a period of between 75 and 100 years and more frequently following. For the calculation of future monitoring and maintenance costs it is assumed that the caps will require replacement every 100 years although this is overly conservative.

The cost of replacing these vertical mine opening caps was estimated to be approximately $70,000 (SENES & SRK 2012) for each cap based on previous experience as well as an additional cost of approximately $70,000 for mobilization, de-mobilization, site preparation and site clean-up.

2.2.3.6 Plug Identified Non-flowing Boreholes

This activity involves applying grout to all identified non-flowing boreholes in the Dubyna Mine area. This activity is considered to be good engineering practice as it reduces the risk that these openings might serve as conduits for mine water in the future.

Plugging non-flowing boreholes will not affect the immediate or downstream environments. Estimated costs of plugging identified non-flowing boreholes are approximately $10,000 CAD.

2.2.4 Dubyna Selection of Remedial Activities

In addition to predicted changes to the environment as assessed by the Beaverlodge QSM (SENES 2012a) and estimated costs of assessed activities (SENES & SRK 2012), opinions expressed during the Beaverlodge Remedial Option Workshop (ASKI, SENES & SRK 2012) can be used as additional information to help inform the remedial activity evaluation process. Outcomes from these three sources are discussed below. In addition, the costs and benefits for each of the remedial measures considered for the Dubyna area are summarized in Table 2.2-2. For each remedial activity expected change to exceedances, predicted reduction in loads, estimated costs as well as calculated cost per unit reduction are presented.

Table 2.2-2 Summary of Predicted Effects of Remedial Activities, Dubyna Area

Remedial Measure	Change to Water Quality or Human/Eco Risk?[a,b]	Reduction in Load to Downstream Environment[c]			Estimated Costs (CAD)	Cost per Unit Reduction[c]			Comments
		Ra-226 (MBq/yr)	Se (kg/yr)	U (kg/yr)		Ra-226 (CAD/kBq/yr)	Se (CAD/g/yr)	U (CAD/g/yr)	
Divert Schmoo Lake outflow around Dubyna Lake	no change to exceedances	8.6 (43%)	0.04 (78%)	48.6 (51%)	$3,200,000	370	73,000	66	-predicted effect on contaminant loads downstream of Dubyna Lake minimal -negative impact on water quality within Dubyna Lake
Place cover on Dubyna waste rock pile	no change to exceedances	0.8 (4%)	-	1.6 (2%)	$3,000,000 to $5,900,000	6,780	-	3,670	-predicted effect on contaminant loads downstream of Dubyna Lake minimal
Plug identified Dubyna area flowing boreholes	no change to exceedances	2.9 (15%)	-	36.6 (38%)	$75,000 (already completed)	25	-	2	-predicted to reduce uranium levels within water column of Dubyna Lake and to lesser degree Ace L. -predicted effect on contaminant loads downstream of Dubyna Lake minimal -good engineering practice
Treat water at the outlet of Dubyna Lake	no change to exceedances	-	-	89.6 (94%)	$35,800,000	-	-	400	-cost of water treatment at the outlet of Dubyna Lake unjustifiably high -additional regulatory licensing requirement -requires ongoing operation and maintenance of treatment facility Immediate reduction in U conc in Ace lake
Replace caps on vertical mine openings	no change to exceedances	-	-	-	$210,000	-	-	-	-good engineering practice -reduces future hazard to those using the site -no predicted effect on contaminant loads
Plug identified non-flowing boreholes	no change to exceedances	-	-	-	$10,000	-	-	-	-no effect on contaminant loads -good engineering practice

Notes:

[a] for the base case scenario (no remediation), there is no predicted risk to any assessed ecological receptors in Ace Lake throughout the modeled period.
[b] human receptors assessed at Ace Lake but not Dubyna Lake
[c] load reductions estimated over the first 50 years after implementation

There is very little predicted benefit to the downstream environment as a result of diverting the Schmoo Lake outflow around Dubyna Lake to Ace Creek. In addition, water quality within Dubyna Lake is predicted to suffer causing increased risk to ecological receptors in the Dubyna area as a result of this activity. For these reasons, this stream diversion was not discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012) and was ruled out as a remedial option.

Installation of a cover on the Dubyna waste rock pile is seen to have very little benefit to the immediate or downstream environment. This activity was included in a remedial scenario evaluated at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). During discussions it became clear quickly that many stakeholders felt that activities to cover waste rock piles throughout the Beaverlodge study area are not justified due to the minimal benefit achieved, the lack of borrow material in the area and the high cost.

In addition to the fact that plugging currently identified flowing boreholes is predicted to reduce radium-226 and uranium levels within Dubyna Lake as well as uranium levels in the water column of Ace Lake, it is considered to be good engineering practice to plug all identified boreholes during remedial works. This activity was discussed during the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012) and, in general, stakeholders were in favour of this activity as it was seen as taking clear action on point sources with relatively low costs. This remedial activity has the most favorable estimated cost per unit reduction of all activities examined for the Dubyna Mine site.

Water treatment at the outlet of Dubyna Lake is predicted to improve uranium levels in Ace Lake; however, predicted risks to receptors in the Ace Lake area were already low without the implementation of any remedial activities. Due to time constraints, this measure was not discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). The estimated cost of water treatment at the outlet of Dubyna Lake is considered by Cameco to be unjustifiably high given the insignificant nature of the benefit achieved downstream; this high cost per unit reduction can be seen in in Table 2.2-2.

Replacing the caps on vertical mine openings in the area is not expected to influence water quality in the area, however, it is considered to be good engineering practice as it reduces the potential for cap failure in the future. Similarly, plugging non-flowing boreholes in the area will not benefit the environment but is considered to be a good engineering practice. These activities will also prepare the site for eventual transfer into the provincial IC Program.

Based on the evaluation presented above, the recommended course of action developed by Cameco for the Dubyna site is to plug the identified flowing and non-flowing boreholes, replace the caps on all vertical mine openings and continue monitoring the area to ensure that recovery is progressing as expected. The other considered activities are not justifiable based on the lack of expected benefit to the local and downstream environment in relation to the cost of implementing the activities.

2.3 HAB MINE SITE

The Hab Mine site is located within the Ace Creek Watershed. The main water body in the Hab area is Pistol Lake, a small lake which receives water from upstream Beatrice Lake. Water exiting Pistol Lake flows south through Mickey Lake (a much larger lake) before entering Ace Lake. The Hab Mine area is shown in Figure 2.3-1.

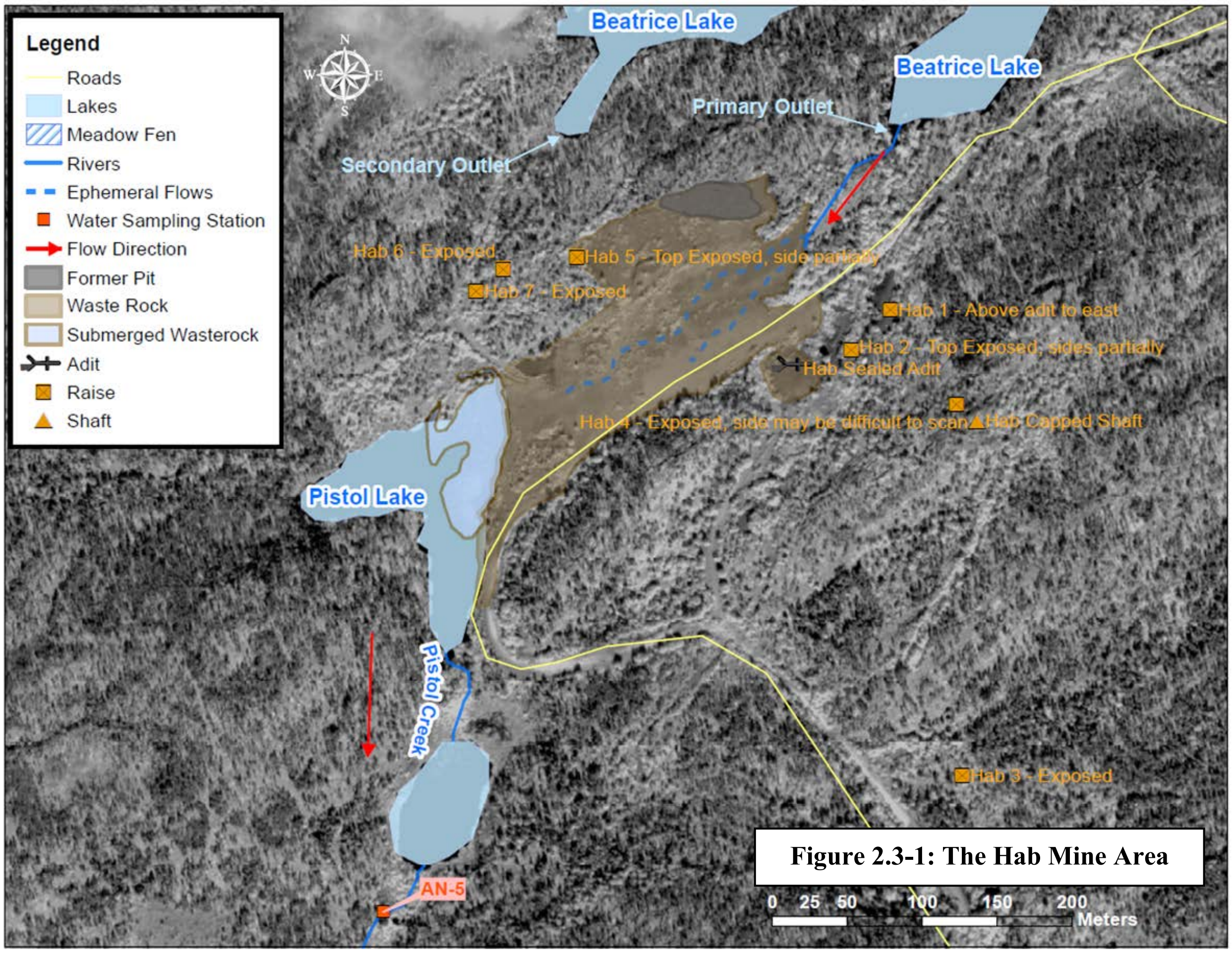


Figure 2.3-1: The Hab Mine Area

2.3.1 Hab Site Features

At the Hab site, the waste rock from both the open pit and underground mine was placed across a valley between Beatrice Lake and Pistol Lake. Some waste rock also occupies a portion of Pistol Lake as indicated in Figure 2.3-1. The outflow from Beatrice Lake may exit the lake at either of two locations depending on beaver activity. The primary outlet (indicated in Figure 2.3-1) flows overland to the base of the waste rock pile, and then disappears. Tracer investigations were not successful in detecting the flow path between the two lakes. It is suspected that a portion (or all) of the surface water outflow from Beatrice Lake may flow into the underground mine workings and not reappear for several weeks/months. It was reported that the Hab underground mine was quite wet over its six-year operating life (from 1970 to 1975). The secondary outlet only flows when beaver activity on the primary outlet raises the Beatrice Lake elevation sufficiently. The secondary channel flows in an undefined channel to the west of the mining area and discharges into Pistol Lake.

Minewater was discharged from the Hab Mine during operation into the area where the waste rock pile is currently located. Historically, minewater originating from the Hab mine was not treated. It is possible that minewater is currently discharging to surface through various openings such as the adit and exploration drill holes but this assumption cannot be verified as the holes are buried beneath the waste rock pile. The effects on water quality downstream from the Hab site is monitored routinely at station AN-5, located downstream of Pistol Lake (see Figure 2.3-1).

2.3.2 Hab Assessment of Potential Risks

In order to select remedial measures, the potential risks that various features within the Hab site may pose to the environment and members of the public accessing the site were assessed. Aspects examined included mining geotechnical; surface water; contaminated substrate; air, radon and gamma; terrestrial and aquatic vegetation; and risk communication. When determining a relative risk rating for each site element likelihood of the event occurring as well as the consequence of that event were considered. The resulting relative risk estimates for the Hab Mine site are shown in Table 2.3-1.

Table 2.3-1 Summary of Estimated Risks, Hab Area

Aspect	Specific Location	Site Element	Current Risk Registry		Risk Endpoints		References
			Event	Effect	Environment Risk	Public Health and Safety Risk	
Mining Geotechnical	**Hab Site**	**Crown Pillar**	Pillar failure (collapse)	Formation of sinkholes creating a falling hazard for wildlife and human	L	ML	Screening Level Risk Assessment, Cameco 2010b.
		Waste Rock pile	Slope instability and failure	Falling hazard for wildlife and human	L	L	Waste Rock Stability Assessments: Former Eldorado Beaverlodge Sites, SRK 2010
		Pit Walls	Walls failure	Hazardous situation for wildlife and human	L	L	Beaverlodge Project: Pit Slope Stability Inspection Report, SRK 2010
			Falling Hazard	Falling event for wildlife and human	L	ML	Screening Level Risk Assessment, Cameco 2010b.
		Demolition Material	Erosion causing exposure of material	Safety concern, e.g. falling hazard	L	ML	Screening Level Risk Assessment, Cameco 2010b.
		Sealed Openings to Surface	Cap failure (9 caps installed)	Formation of opening (vertical hole) to underground workings creating a falling hazard for wildlife and human	M	M	Departure With Dignity: Decommissioning of the Beaverlodge Mine/Mill. MacLaren Plansearch 1987.
			Slumping (2 adits filled with waste rock)	Open access to workings	L	ML	Departure With Dignity: Decommissioning of the Beaverlodge Mine/Mill. MacLaren Plansearch 1987.
Surface Water (including Flowing Drillholes)	**Hab Site**	**Waste Rock pile**	Leaching of mine slimes deposited in waste rock to Pistol Lake	Impact on Pistol Lake water quality and ecosystem effects	M	L	Beaverlodge Quantitative Site Model. SENES 2012a. Results of Field Investigations in the Areas of the Decommissioned Fay-Verna, Hab and Dubyna Mines, Golder 2010.
			Surface runoff and precipitation infiltration through the waste rock into Pistol Lake	Impact on Pistol Lake water quality and ecosystem effects	ML	L	Beaverlodge Quantitative Site Model. SENES 2012a. Results of Field Investigations in the Areas of the Decommissioned Fay-Verna, Hab and Dubyna Mines, Golder 2010.
		Flowing Drill Holes and Other Conduits for Mine Water Flow	Seepage to surface water	Impact on Pistol Lake water quality and ecosystem effects	M	L	Beaverlodge Quantitative Site Model. SENES 2012a. Results of Field Investigations in the Areas of the Decommissioned Fay-Verna, Hab and Dubyna Mines, Golder 2010.
		Demolition Material	Erosion of demolition material and discharge to Pistol Lake	Impact on Pistol Lake water quality and ecosystem effects	ML	L	Screening Level Risk Assessment, Cameco 2010b.
	Pistol Lake	**Beaver Dam**	Dam Failure	Reduction in size of Pistol Lake and loss of aquatic habitat	L	L	Screening Level Risk Assessment, Cameco 2010b.
				Physical degradation of channel and loss of habitat	ML	L	Screening Level Risk Assessment, Cameco 2010b.
				Flushing of contaminants downstream	ML	L	Beaverlodge Quantitative Site Model, SENES 2012a.
				Exposure of potentially contaminated sediments	ML	L	Beaverlodge Quantitative Site Model, SENES 2012a.
				Downstream deposition of contaminated sediments	ML	L	Beaverlodge Quantitative Site Model, SENES 2012a.
		Pistol Lake water	Discharge to downstream waters	Impact on water quality in Mickey and Ace lakes and impact on aquatic biota	ML	L	Beaverlodge Quantitative Site Model. SENES 2012a. Aquatic Macrophyte Sampling Program. CanNorth 2011a.
	Beatrice Lake	**Beatrice outflow**	Channel flowing through waste rock and/or underground mine workings to Pistol Lake	Impact on Pistol Lake water quality	M	L	Beaverlodge Quantitative Site Model. SENES 2012a. Results of Field Investigations in the Areas of the Decommissioned Fay-Verna, Hab and Dubyna Mines, Golder 2010.
			Failure of beaver dam on Beatrice Outflow and erosion of waste rock causing contaminant flushing	Impact on water quality in Pistol, Mickey and Ace lakes and ecosystem effects	ML	L	Screening Level Risk Assessment, Cameco 2010b.

Table 2.3-1 Summary of Estimated Risks, Hab Area (Cont'd)

Aspect	Specific Location	Site Element	Current Risk Registry		Risk Endpoints		References
			Event	Effect	Environment Risk	Public Health and Safety Risk	
Contaminated Substrate	**Pistol Lake**	**Substrate**	Accumulation of contaminants in sediment	Impact on Pistol Lake water quality	ML	L	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009. Deep Basin Sediment Study. CanNorth 2012. Aquatic Macrophyte Sampling Program. CanNorth 2011a.
Air, Radon and Gamma	**Hab Site**	**Waste Rock**	Dusting of waste rock and release of airborne contaminants	Inhalation exposure for wildlife and human	L	L	Screening Level Risk Assessment, Cameco 2010b.
			Radon release from exposed rock	Prolonged radon exposure for wildlife and human	ML	L	Screening Level Risk Assessment, Cameco 2010b.
			Gamma exposure from waste rock	Prolonged gamma exposure for wildlife and human	L	L	Screening Level Risk Assessment, Cameco 2010b.
		Pit Walls	Gamma exposure from pit walls	Prolonged gamma exposure for wildlife and human	L	L	Screening Level Risk Assessment, Cameco 2010b.
Terrestrial and Aquatic Vegetation	**General**	**Terrestrial Vegetation**	Release of COPC to air	Potential uptake of contaminants in vegetation and impact to VECs	L	L	Beaverlodge Quantitative Site Model. SENES 2012a. Country Foods Survey. SENES 2012b. Draft.
	Pistol Lake	**Aquatic Vegetation**	Leaching of COPC to water	Potential uptake of contaminants in vegetation and impact to VECs	ML	L	Beaverlodge Quantitative Site Model. SENES 2012a. Aquatic Macrophyte Sampling Program. CanNorth 2011a. Country Foods Survey. SENES 2012b. Draft.
Risk Communication	**General**	**-**	Public notification of any site risk	If not done in a timely manner may cause public safety risk	L	L	Screening Level Risk Assessment, Cameco 2010b.

As can be seen in Table 2.3-1, potential events which were estimated to pose the greatest risk to the environment and public accessing the site include failure of caps on vertical mine openings, leaching of mine slimes from within the waste rock pile, seepage to surface water through unidentified drill holes and other conduits, and water flowing through the waste rock pile and/or underground workings to Pistol Lake; remedial measures examined within the following section are focused on these features and potential events. It should be noted that none of the risks from this property are ranked 'high'.

2.3.3 Hab Assessment of Remedial Activities

Potential remedial measures considered based on identified risks within the Hab Mine site and/or to meet the standard of good engineering practice:

- Divert Beatrice Lake outflow to prevent contact with waste rock
- Reshape and cover Hab waste rock pile
- Excavate waste rock and plug boreholes and other mine openings
- Backfill Pistol Lake
- Treat water at outlet of Pistol Lake for radium-226 and uranium removal
- Replace caps on vertical openings
- Plug identified non-flowing boreholes

Each of these activities will be discussed in the following sections. It should be noted that there is uncertainty regarding the hydrogeology of this area including flow through the waste rock pile and underground mine workings.

2.3.3.1 Beatrice Lake Outflow Diversion

Two stream diversions were considered for this site. Both stream diversions involve activities to limit Beatrice Lake outflow contact with the waste rock pile and possibly with the underground mine workings. The first scenario requires construction of a dam at the primary outlet of Beatrice Lake (shown in Figure 2.3-1) and construction of a new channel which would force the outflow from Beatrice Lake to the western arm of Beatrice Lake to Pistol Lake, bypassing the waste rock pile. The second scenario involves installation of an HDPE liner down the original flow path to limit contact with the surrounding waste rock.

There is uncertainty around whether either of these diversions would be effective in eliminating any existing flow through underground mine workings. In addition, there is a high level of beaver activity at the outlet of Beatrice Lake, making the long-term success of these diversions unpredictable.

Potential change to environmental conditions based on these stream diversions were assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year

2015 for modeling purposes. Assumptions which were made in order to predict the effects of this activity are:

- Overall, it was assumed that 70% of the Beatrice Lake outflow flows through the underground mine workings while the remaining 30% passes through the waste rock pile. This flow breakdown is supported by available data and discussion can be found in the Beaverlodge Quantitative Site Model report (SENES 2012a). This breakdown is uncertain as available data regarding the hydrogeology of the region is limited.
- It was assumed that both diversions are able to successfully eliminate 50% of the Beatrice Lake flow assumed to pass through the mine as it is entirely possible that a large portion of the stream will continue to access the underground mine workings even after diversion away from the waste rock pile. Additionally, it was assumed that 100% of the Beatrice Lake flow assumed to pass through the waste rock would be successfully diverted directly to Pistol Lake.

These assumptions result in a predicted reduction in radium-226 load of 53% and a reduction in uranium load of 45% to the downstream environment. It is important to note that, given the uncertainty regarding effectiveness of this remedial activity, the predicted benefit of this measure cannot be quantified with accuracy and that these predictions may overestimate the possible benefit.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.3-2, 2.3-3 and 2.3-4. As can be seen, while some significant reductions in uranium and radium-226 are predicted in the immediate area (Pistol Lake), these results are not translated into improvements in the downstream environment (Mickey and Ace lakes). It should be noted that Pistol Lake is a small (1.2 ha), shallow, non-fish bearing water body which has been found to have a limited ecosystem and that water quality in Mickey Lake is predicted to remain below the water quality guidelines throughout the modeled period even in the base case scenario. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.3-5 and 2.3-6 for Pistol Lake and Ace Lake as compared to the base case, with no remediation. As can be seen, there are no predicted risks to ecological receptors at Ace Lake with or without implementation of these diversions.

In addition to the uncertainty regarding the success of these stream diversions, it should be noted that these diversions involve perpetual maintenance of either the dam structure at the outlet of Beatrice Lake or the installed HDPE channel.

Costs of these stream diversions were estimated by SRK (2011) and further discussed in SENES & SRK (2012) to be approximately $1 million CAD each including the NVP of a $10,000 CAD per year maintenance cost in perpetuity in both cases.

Figure 2.3-2 Pistol Lake Water Quality Predictions (Divert Beatrice Lake Outflow)

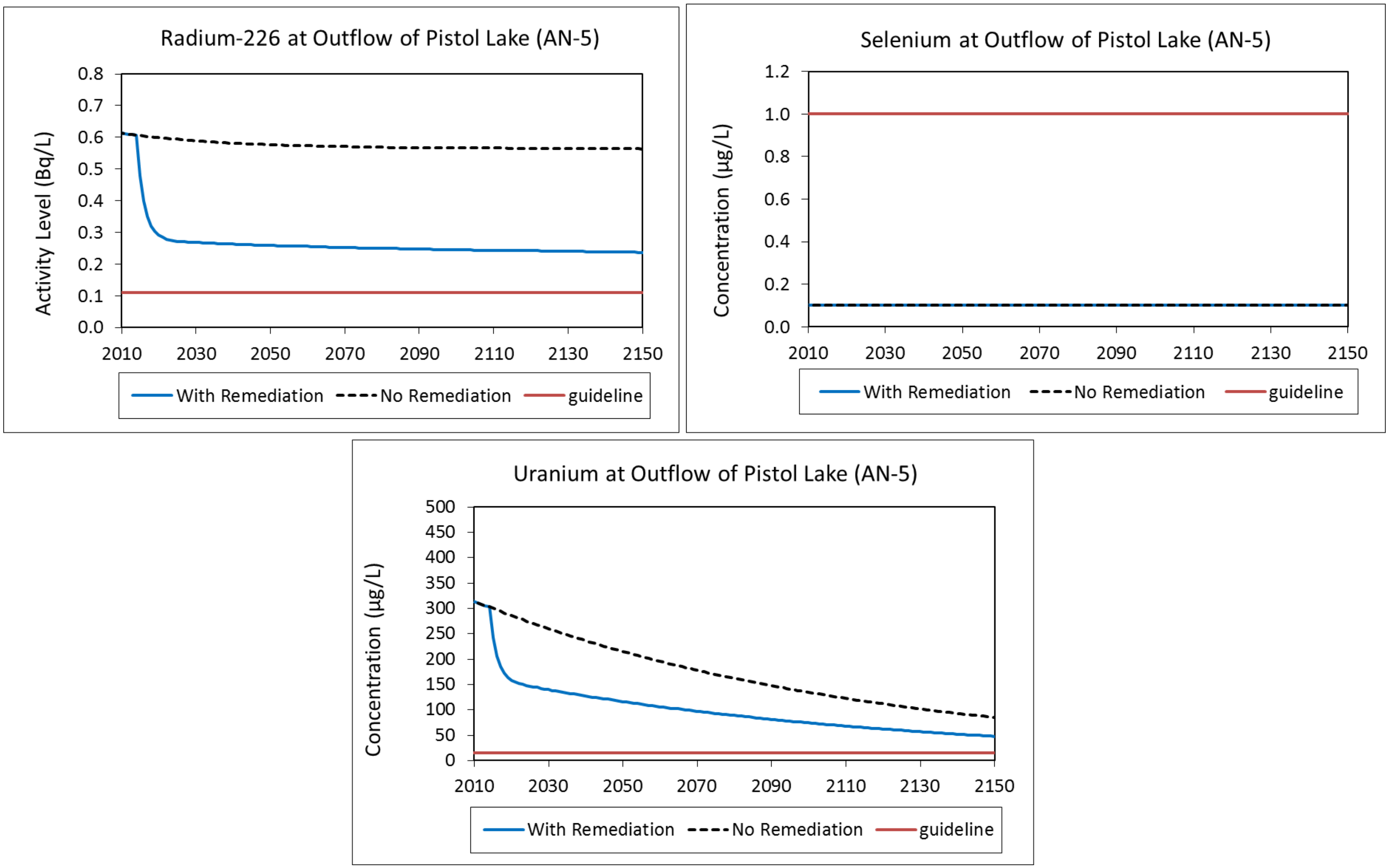
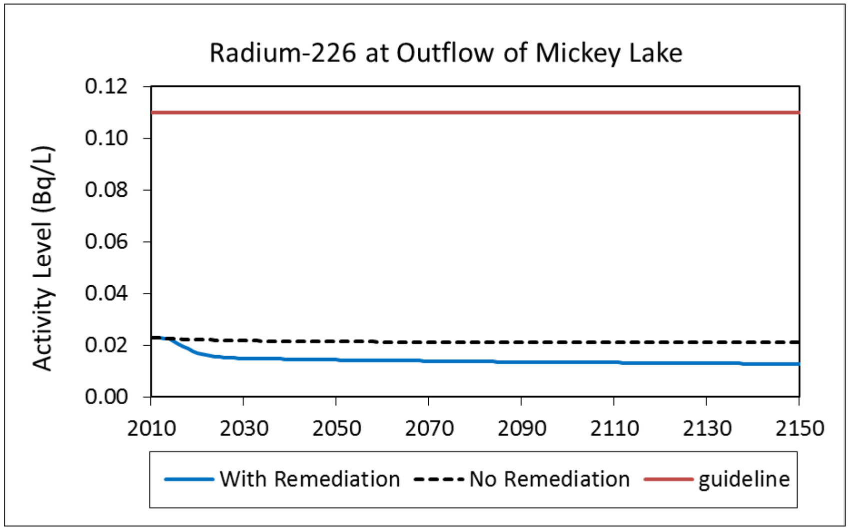
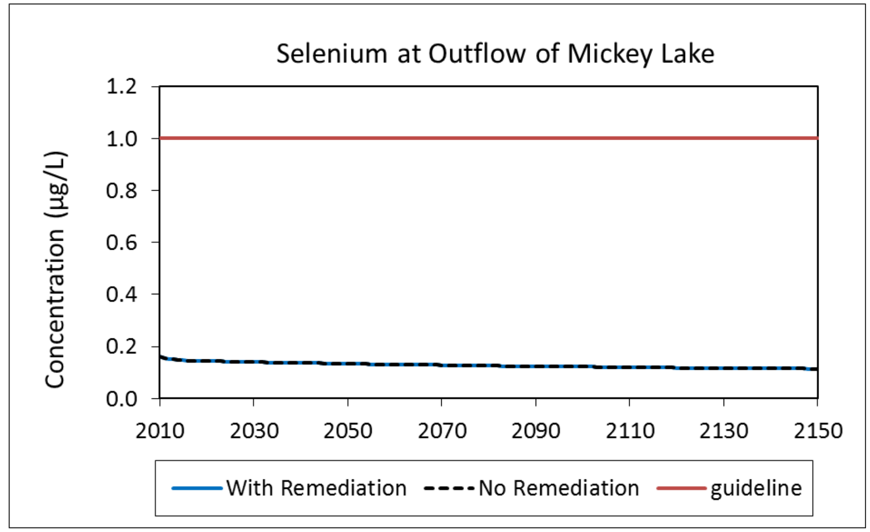


Figure 2.3-3 Mickey Lake Water Quality Predictions (Divert Beatrice Lake Outflow)





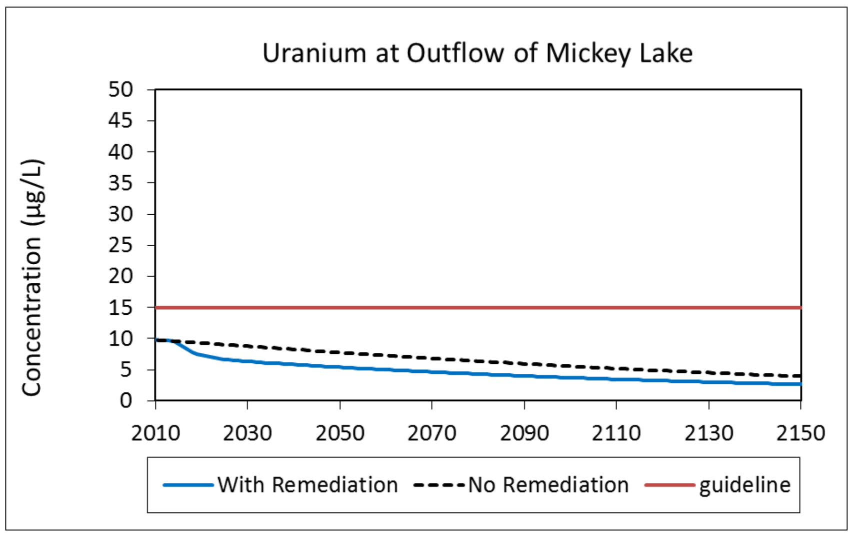


Figure 2.3-4 Ace Lake Water Quality Predictions (Divert Beatrice Lake Outflow)

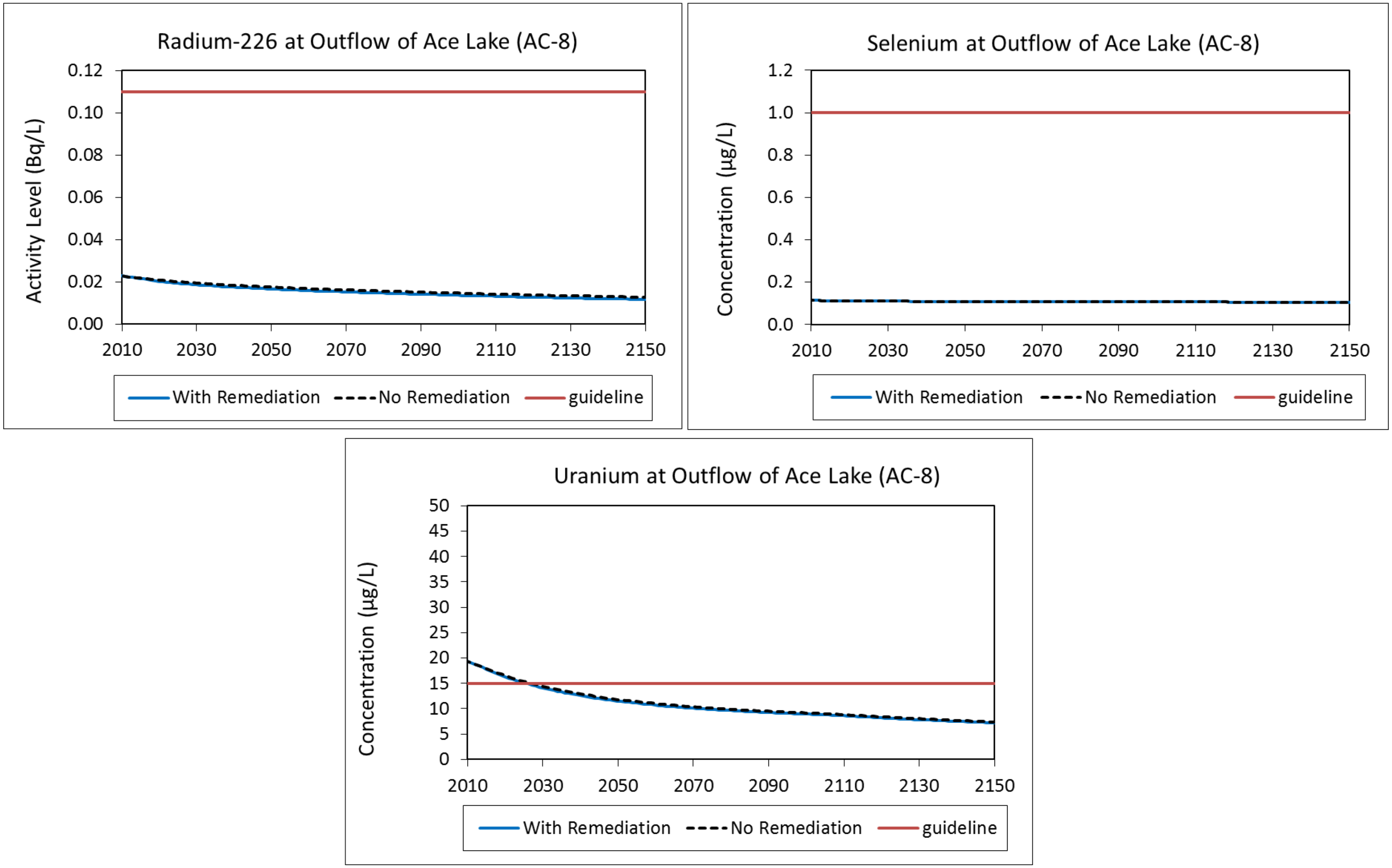


Figure 2.3-5 Summary of Outcomes in Pistol Lake (Divert Beatrice Lake Outflow)

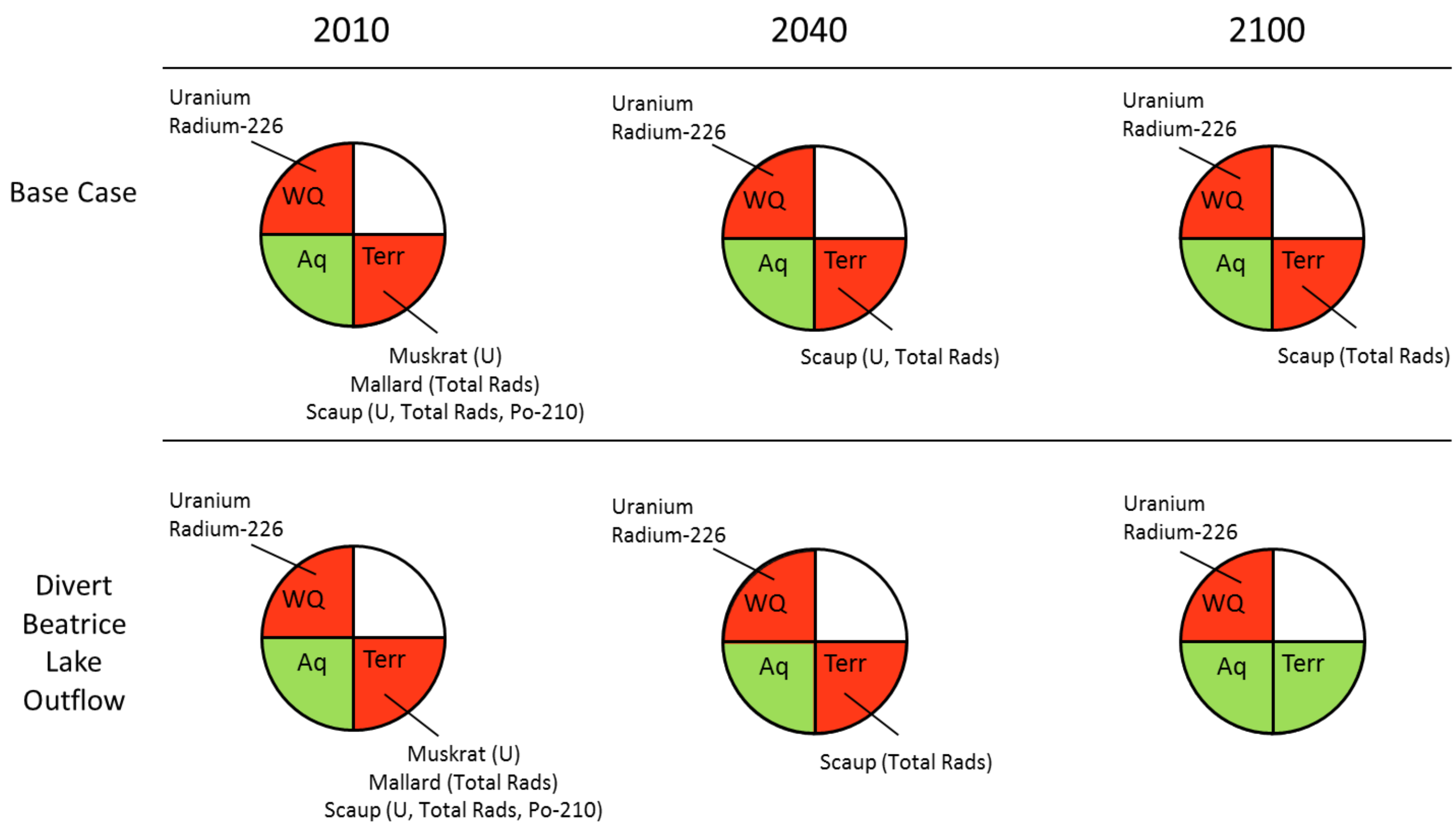
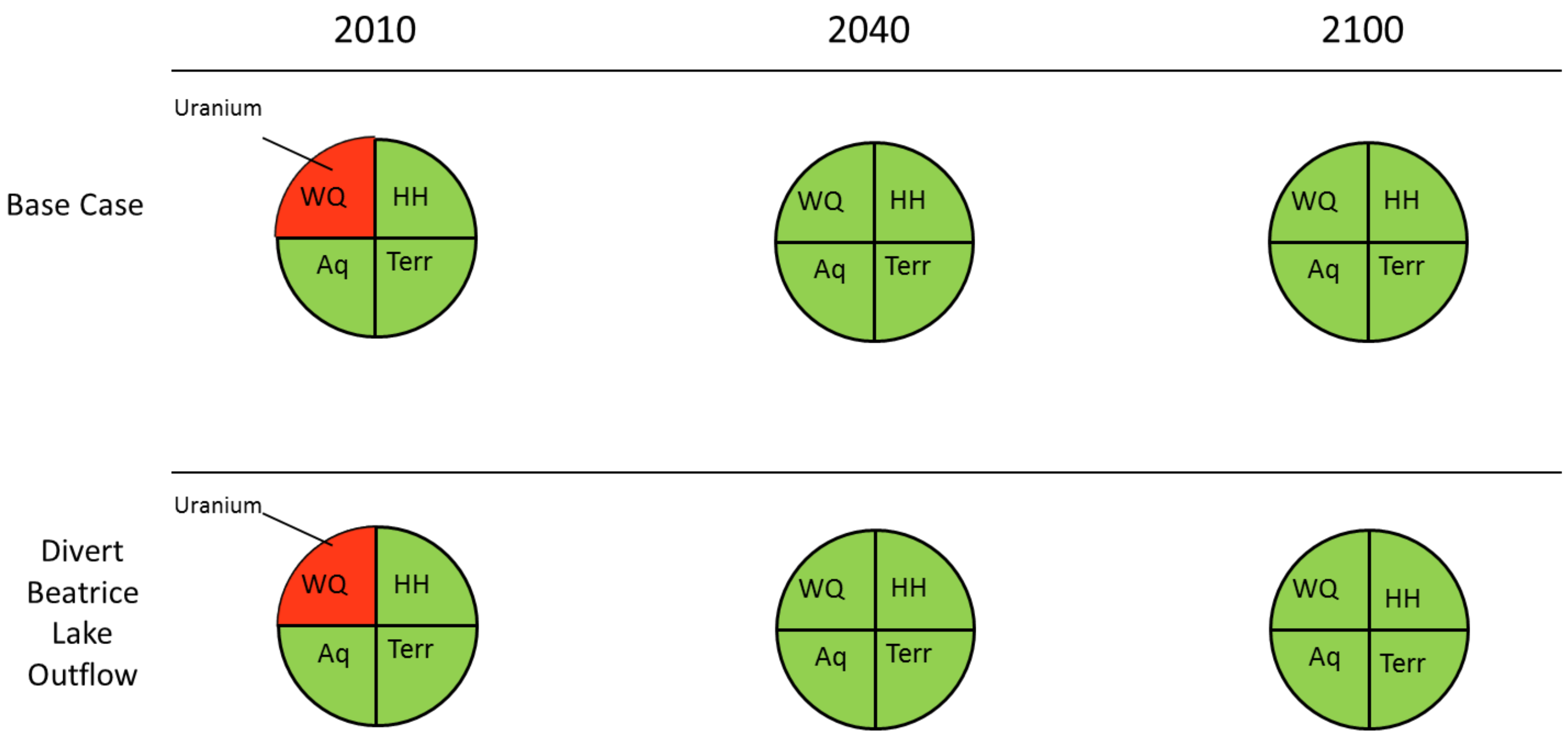


Figure 2.3-6 Summary of Outcomes in Ace Lake (Divert Beatrice Lake Outflow)



2.3.3.2 Reshape and Cover Hab Waste Rock Pile

This remedial measure involves reshaping and installing a cover on the waste rock pile in the Hab Mine area. The pile would be re-contoured to fit the surrounding landscape then covered with either a sand layer or a geosynthetic liner (such as HDPE). It should be noted that placement of a cover on the Hab waste rock pile only reduces the flow of precipitation down through the pile and does not affect the much larger stream flowing through the pile and underground workings from Beatrice Lake.

Potential change to environmental conditions based on reshaping and covering the waste rock pile in the Hab area was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- As discussed in SENES & SRK (2012), with proper installation of a geo-synthetic liner such as the one discussed in this section, the percolation rates in the waste rock may be reduced to ~5% from 39%. The reduction in percolation through the waste rock pile is predicted to be much less with a sand cover, however, this option was assessed assuming the best case scenario.
- The annual precipitation rate for the region and base case percolation rate for the waste rock pile are discussed in SENES (2012) and were assumed to be 273 mm/a and 39%, respectively.

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 6% from 4.8×10^4 kBq/yr to 4.5×10^4 kBq/yr and a reduction in uranium load of 4% from 19.7 kg/yr to 19.0 kg/yr to the downstream environment.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.3-7, 2.3-8 and 2.3-9. A very small decrease in radium-226 and uranium levels is seen in Pistol Lake as a result of reshaping and covering the waste rock pile; almost no change is apparent for selenium in Pistol Lake or any of the three parameters in Mickey and Ace lakes. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.3-10 and 2.3-11 for Pistol Lake and Ace Lake as compared to the base case, with no remediation. It should be noted that Pistol Lake is a small (1.2 ha), non-fish bearing water body which has been found to have a limited ecosystem. As can be seen, reshaping and applying a cover to the Hab waste rock pile does not change the exceedances noted for ecological receptors in Pistol Lake and no exceedances are noted for receptors in the Ace Lake area with or without implementation of this remedial measure. The results presented here are for application of a geo-synthetic liner and that if a sand cover is selected instead, benefit of this activity would be even less.

Costs of reshaping and covering the Hab waste rock pile were estimated by SENES & SRK (2012) to be between approximately $1.5 and $2.8 million CAD for sand and geo-synthetic covers, respectively. These estimated costs include the NPV of an annual $10,000 CAD per year maintenance expense.

Figure 2.3-7 Pistol Lake Water Quality Predictions (Reshape and Cover Waste Rock)

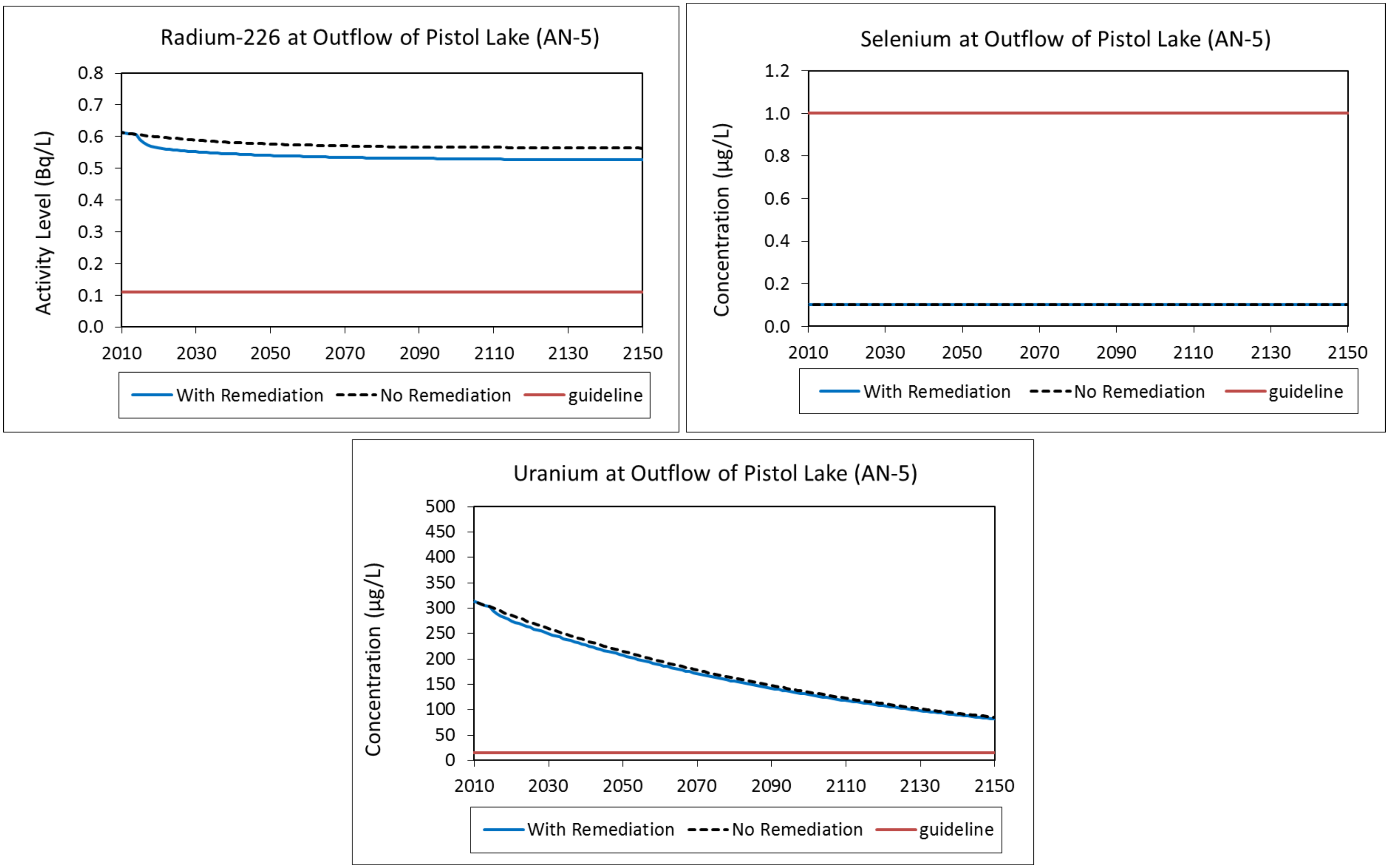


Figure 2.3-8 Mickey Lake Water Quality Predictions (Reshape and Cover Waste Rock)

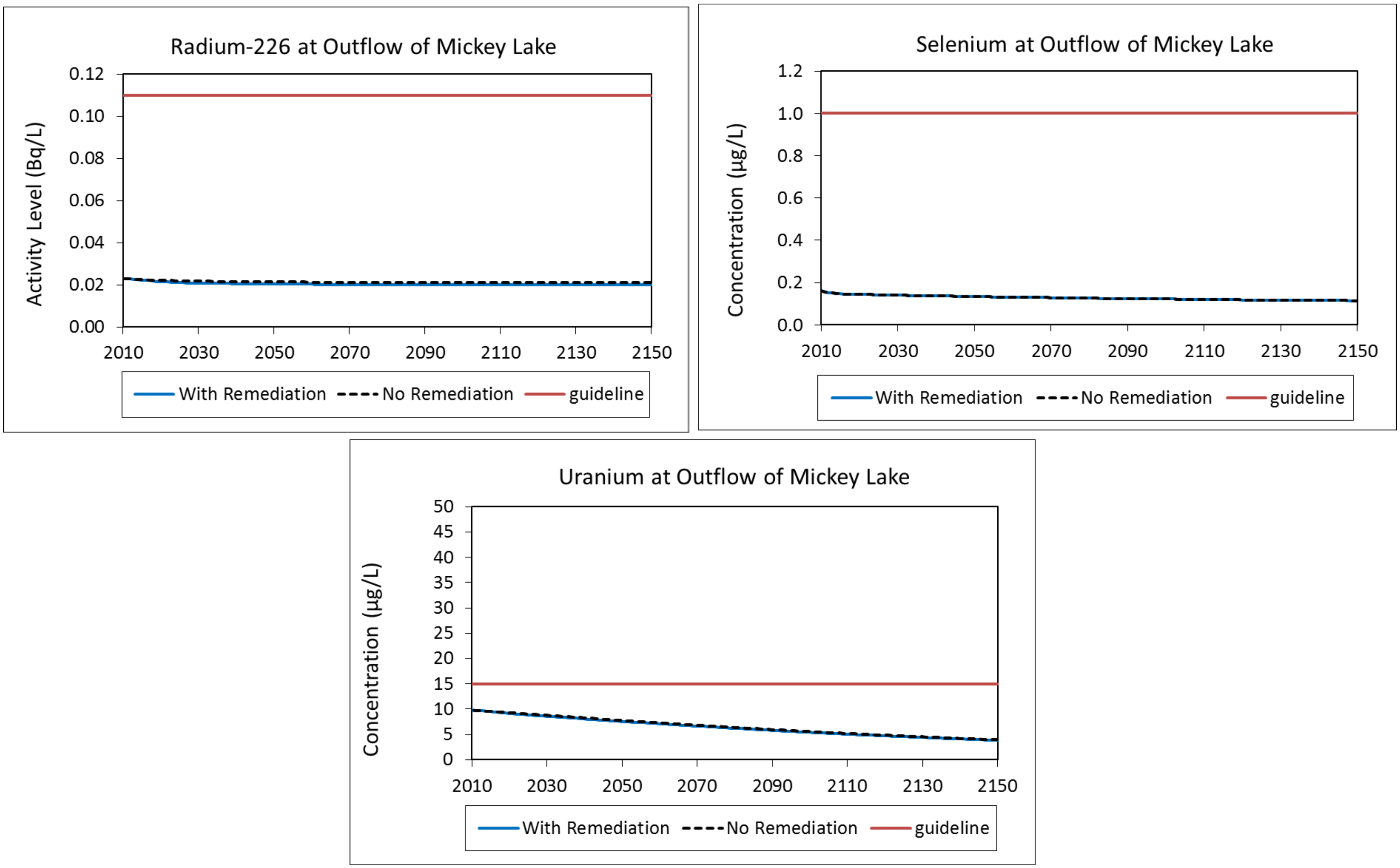


Figure 2.3-9 Ace Lake Water Quality Predictions (Reshape and Cover Waste Rock)

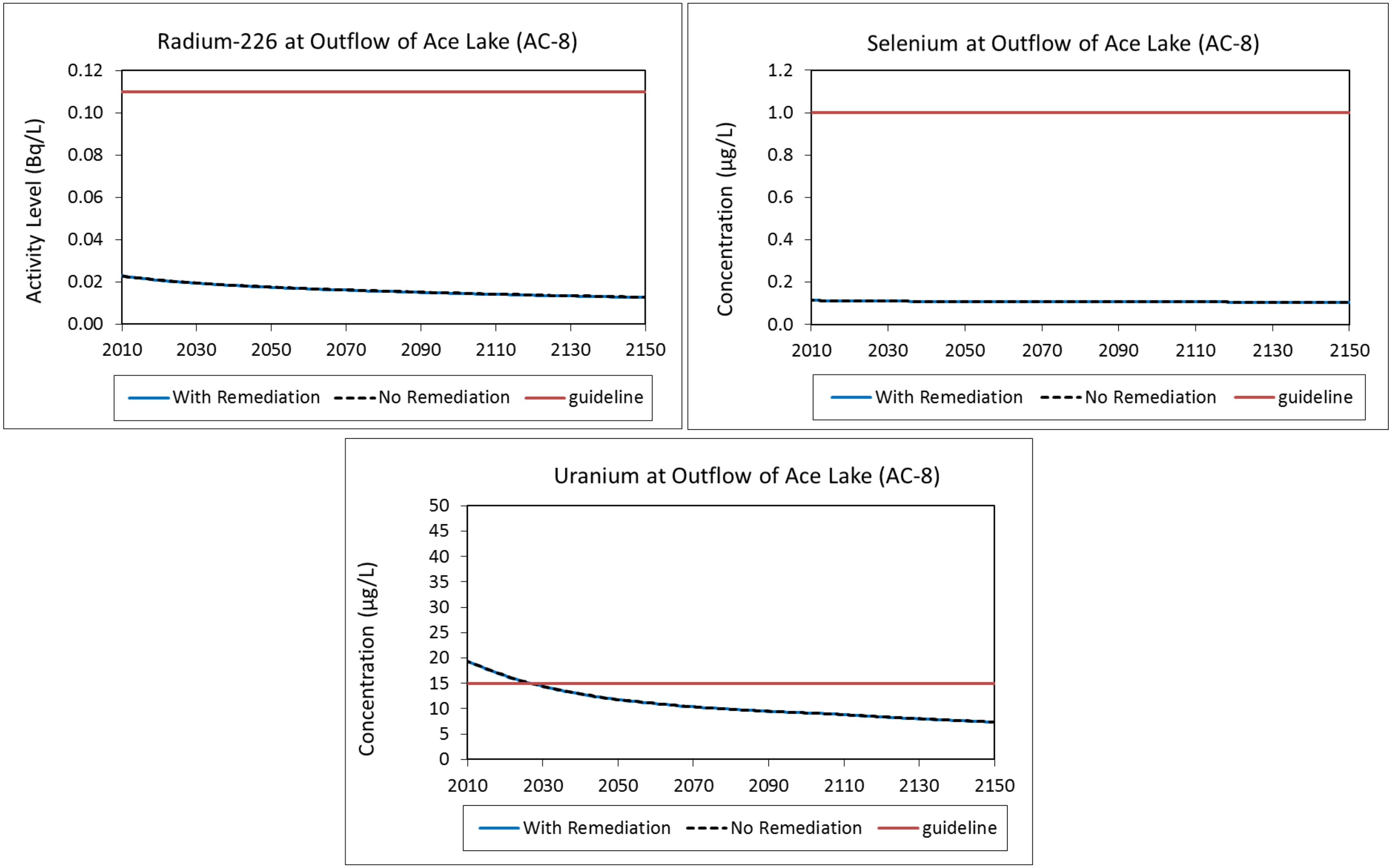


Figure 2.3-10 Summary of Outcomes in Pistol Lake (Reshape and Cover Waste Rock)

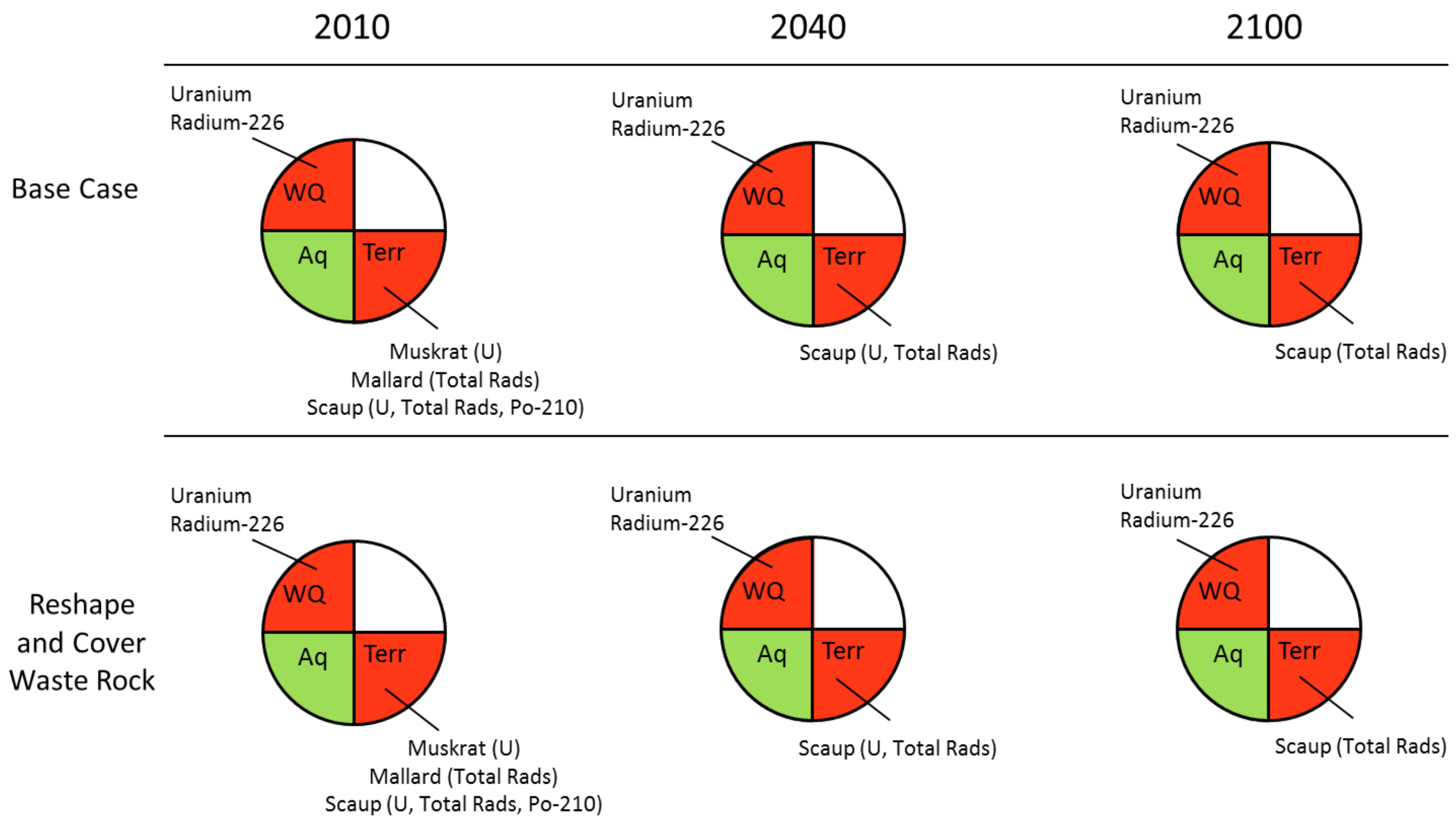
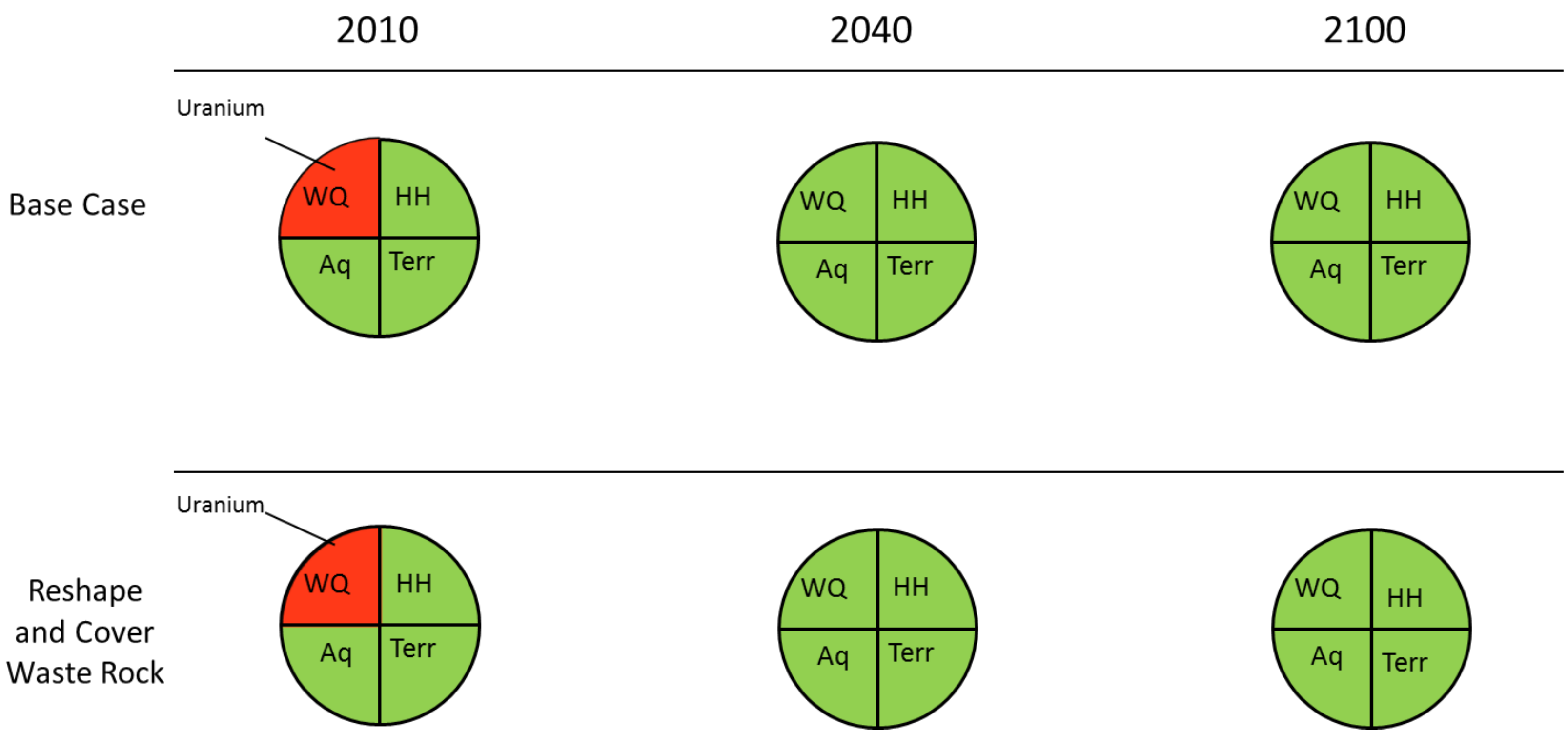


Figure 2.3-11 Summary of Outcomes in Ace Lake (Reshape and Cover Waste Rock)



2.3.3.3 Excavate Waste Rock to Plug Boreholes and Other Mine Openings

This activity involves searching for boreholes or mine openings through which contaminated mine water could potentially be flowing and plugging them to reduce the outflow. The success and cost of this activity are uncertain as the location of mine openings and the associated flows are unknown. There may be open boreholes located under the waste rock pile and even within Pistol Lake itself.

Potential change to environmental conditions based on plugging Hab area mine openings was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- As there is uncertainty regarding the success of this activity, it was assumed, most likely optimistically, that 80% of the flow could be located and stopped from entering the Hab mining area.

These assumptions result in a predicted reduction in radium-226 load of 26% and a reduction in uranium load of 35% to the downstream environment. It is important to note that, given the uncertainty regarding effectiveness of this remedial activity, the predicted benefit of this measure cannot be quantified with accuracy and that these predictions may overestimate the possible benefit.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.3-12, 2.3-13 and 2.3-14. Similar to the stream diversion discussed above, while some reductions in uranium and radium-226 are seen in the immediate area (Pistol Lake), these results are not translated into significant improvements in the downstream environment (Mickey and Ace lakes). A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.3-15 and 2.3-16 for Pistol Lake and Ace Lake as compared to the base case, with no remediation. As can be seen, there are no predicted risks to ecological receptors in the Ace Lake area with or without implementation of this remedial activity. Pistol Lake is a small (1.2 ha), non-fish bearing water body which has been found to have a limited ecosystem.

Costs of excavating the Hab waste rock pile to expose and plug boreholes and other mine openings was estimated by SENES & SRK (2012) to be approximately $2.2 million CAD plus approximately $75,000 CAD for each additional borehole discovered. It is unclear how successful moving waste rock will be at exposing flowing boreholes. It should be noted that the model predictions do not attempt to account for the potential negative impacts of exposing additional waste rock to weathering during implementation of this remedial measure. As well, the costs for plugging any other flowing mine openings are uncertain and will depend on the individual location and nature of the opening. All identified boreholes on the property will be grouted.

Figure 2.3-12 Pistol Lake Water Quality Predictions (Plug Hab Area Mine Openings)

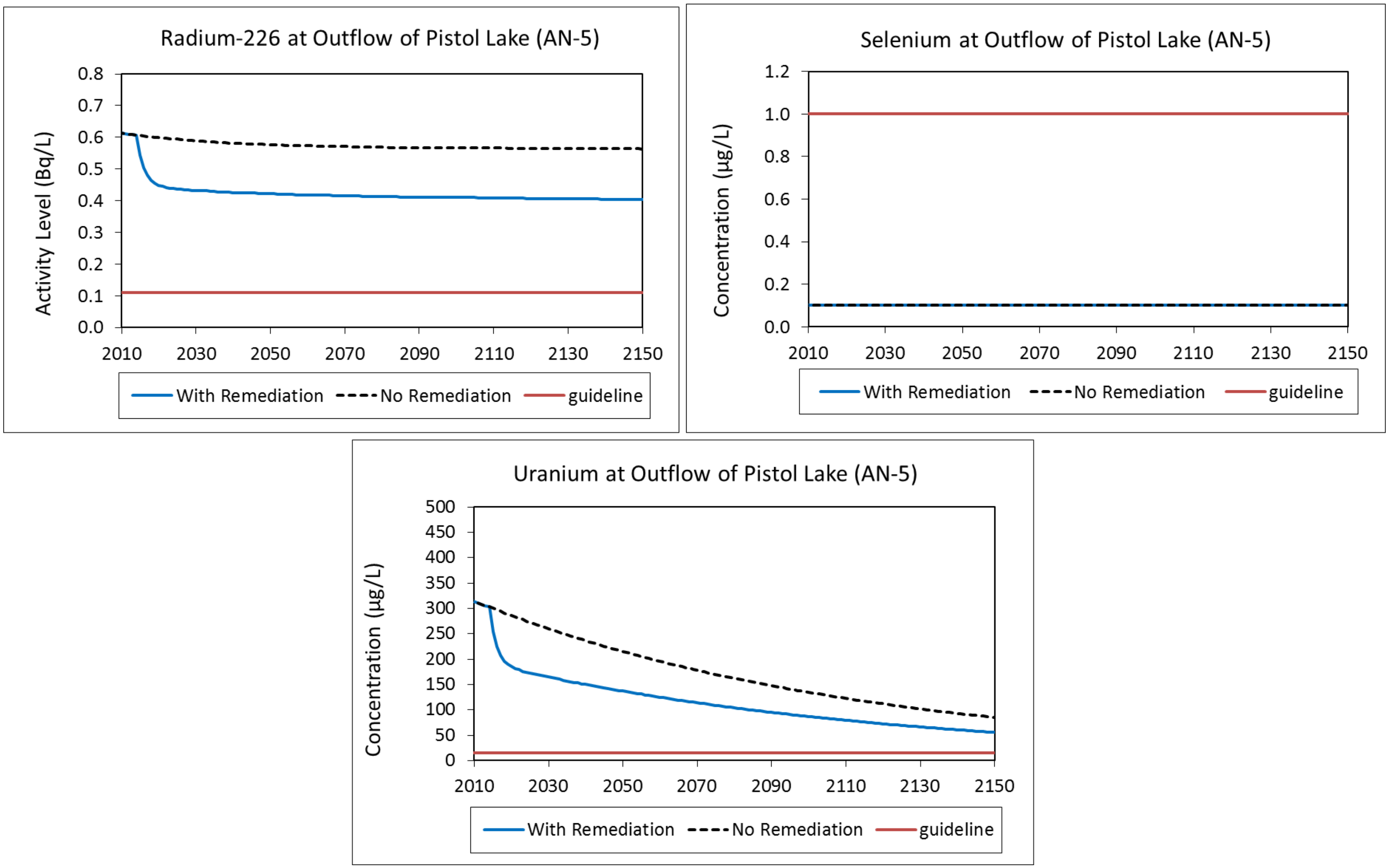


Figure 2.3-13 Mickey Lake Water Quality Predictions (Plug Hab Area Mine Openings)

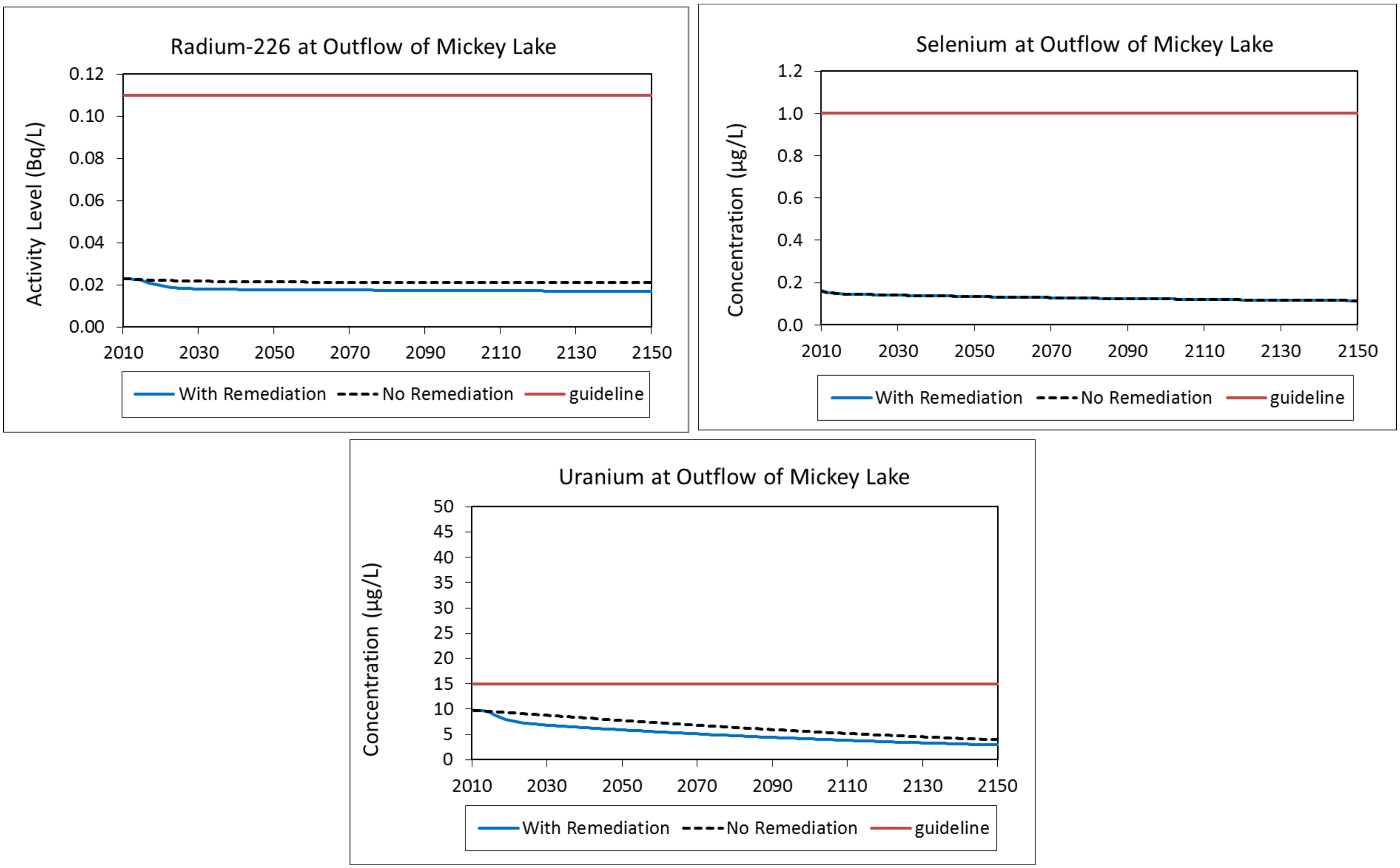


Figure 2.3-14 Ace Lake Water Quality Predictions (Plug Hab Area Mine Openings)

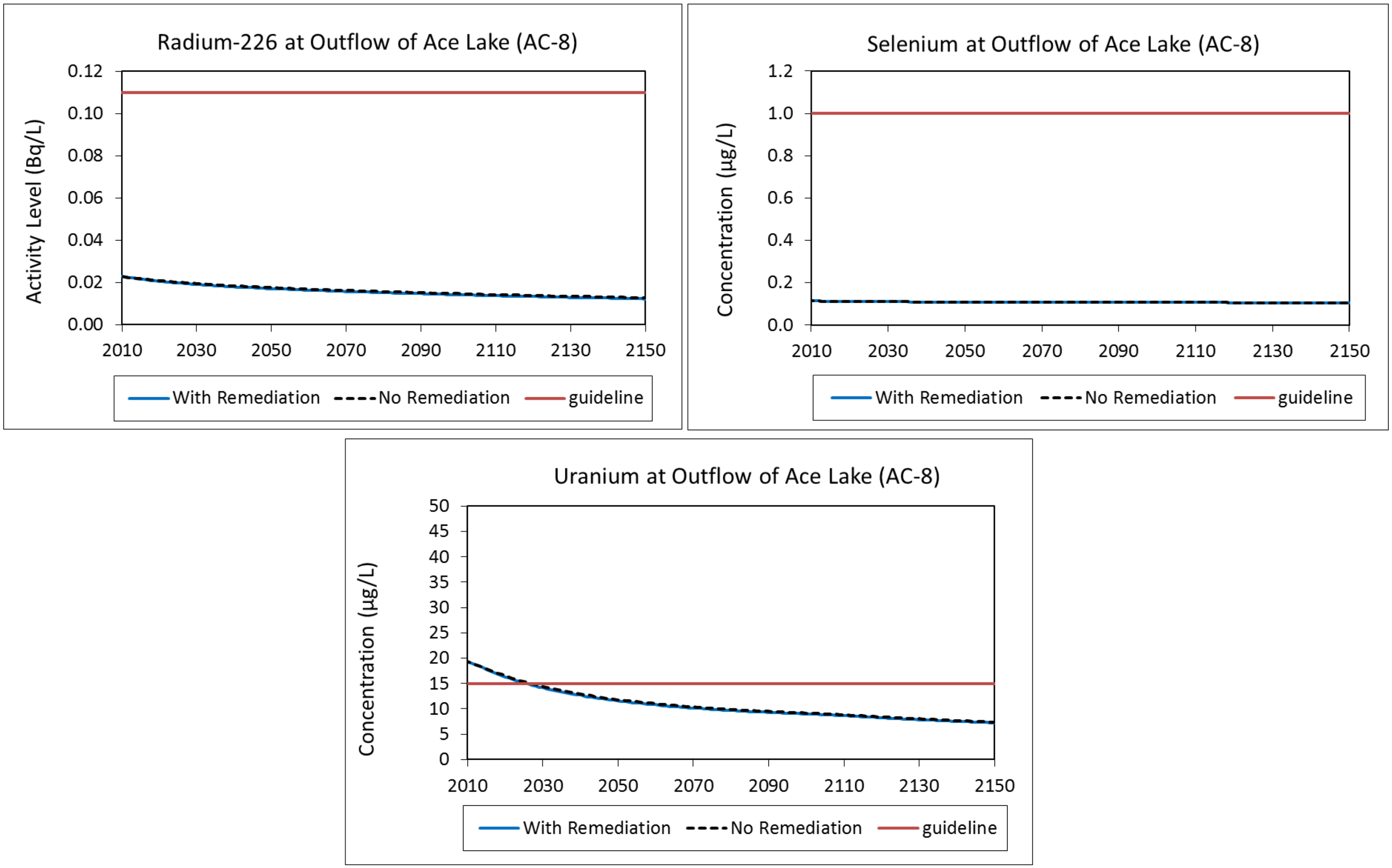


Figure 2.3-15 Summary of Outcomes in Pistol Lake (Plug Hab Area Mine Openings)

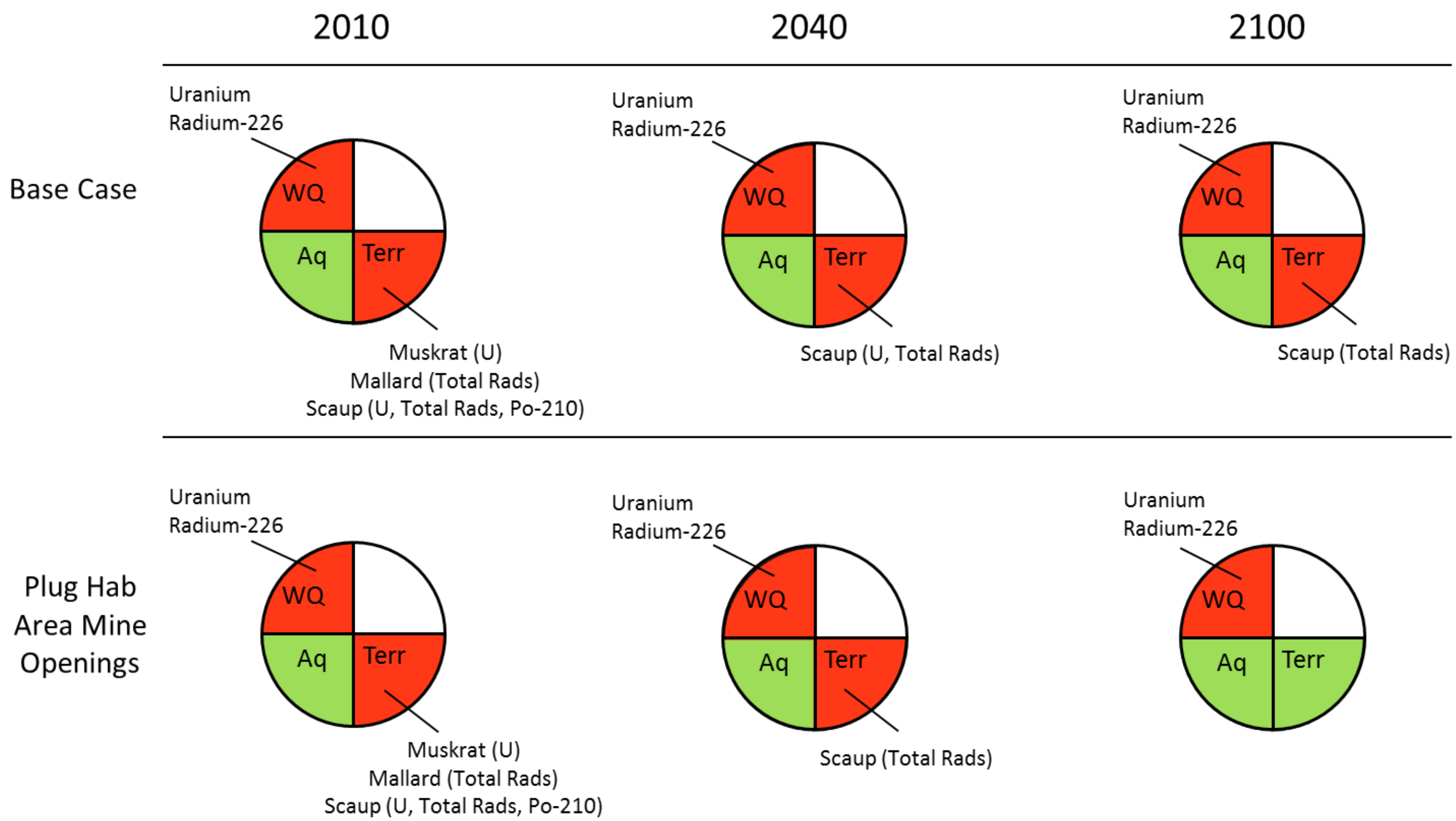
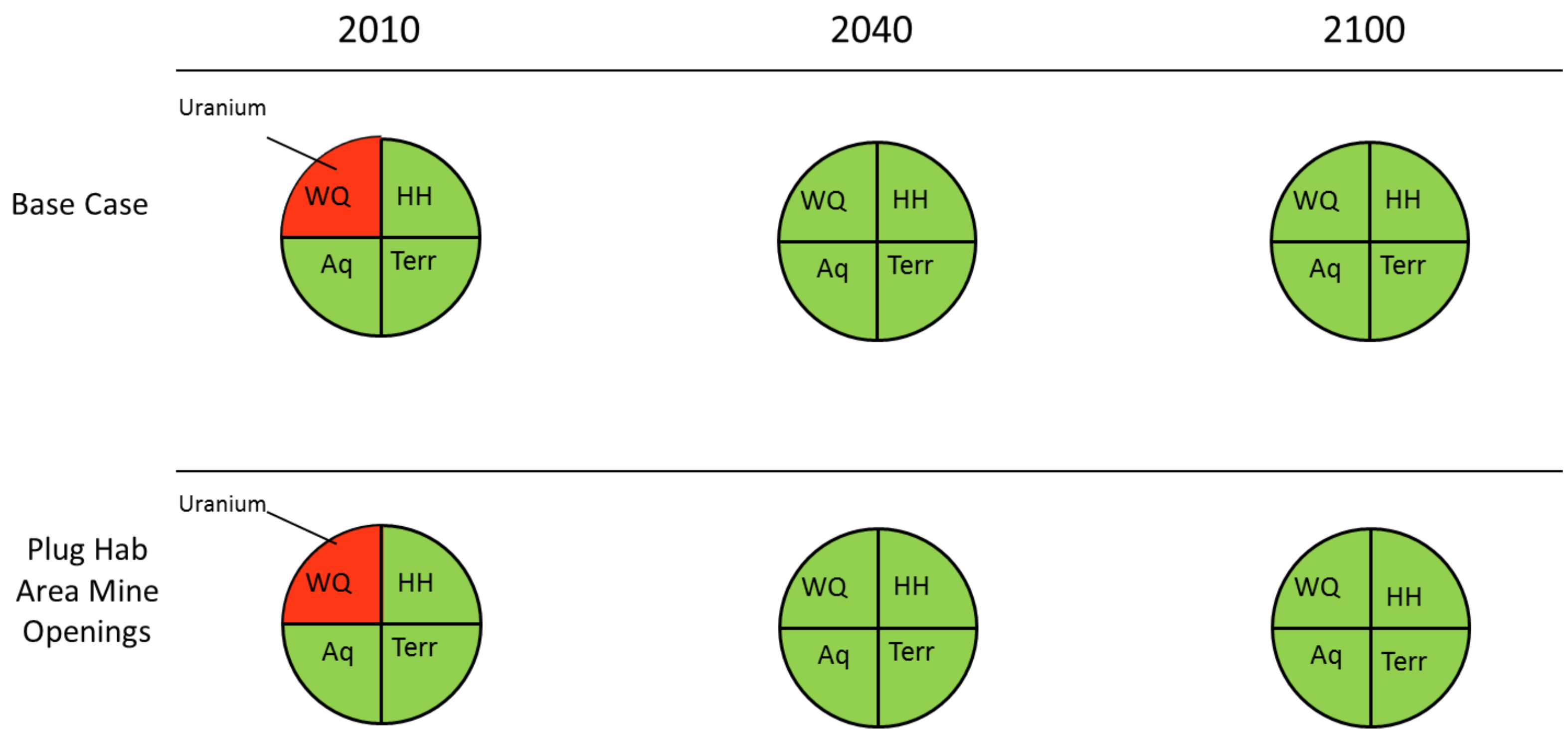


Figure 2.3-16 Summary of Outcomes in Ace Lake (Plug Hab Area Mine Openings)



2.3.3.4 Backfill Pistol Lake

This activity involves backfilling Pistol Lake with clean material. This activity would not only reduce the release of constituents from sediments and subaqueous waste rock in the lake bed but would also eliminate a large portion of the lake and therefore wildlife access to the water.

Potential effects of backfilling Pistol Lake were assessed using the Beaverlodge QSM (SENES 2012a) assuming these activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- Load from external sources (waste rock pile and underground mine workings) remain unchanged
- Fill material assumed to be at background sediment concentrations for the area
- Minimal mixing of original sediments with fill material at the surface
- Nominal water volume of approximately 1,350 m^3 remains in Pistol Lake (SRK 2011)

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 0.5% and a reduction in uranium load of 1.6% to the downstream environment.

Predicted water quality in the downstream environment over the 2010-2150 period is shown in Figures 2.3-17 and 2.3-18. Similar to the other remedial measures discussed above, significant improvements in the downstream environment (Mickey and Ace lakes) are not seen. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.3-19 and 2.3-20 for Ace Lake as compared to the base case, with no remediation. As can be seen, there are no predicted risks to ecological receptors in the Ace Lake area with or without implementation of this remedial measure. Pistol Lake is a small (1.2 ha), non-fish bearing water body which has been found to have a limited ecosystem.

Costs of backfilling activities were estimated by SRK (2011) and further discussed by SENES & SRK (2012) to be approximately $900,000 CAD.

Figure 2.3-17 Pistol Lake Water Quality Predictions (Backfill Pistol Lake)

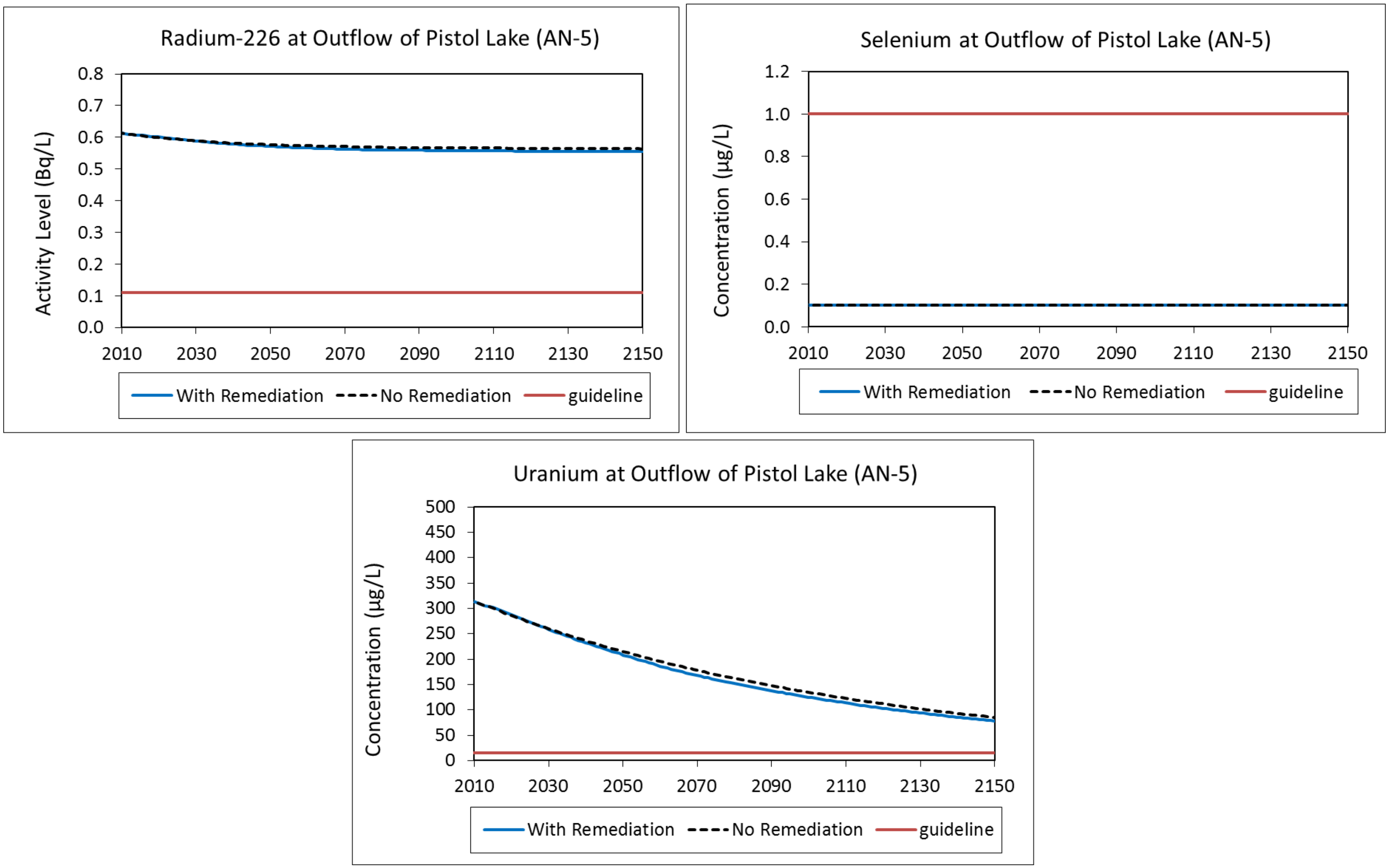


Figure 2.3-18 Mickey Lake Water Quality Predictions (Backfill Pistol Lake)

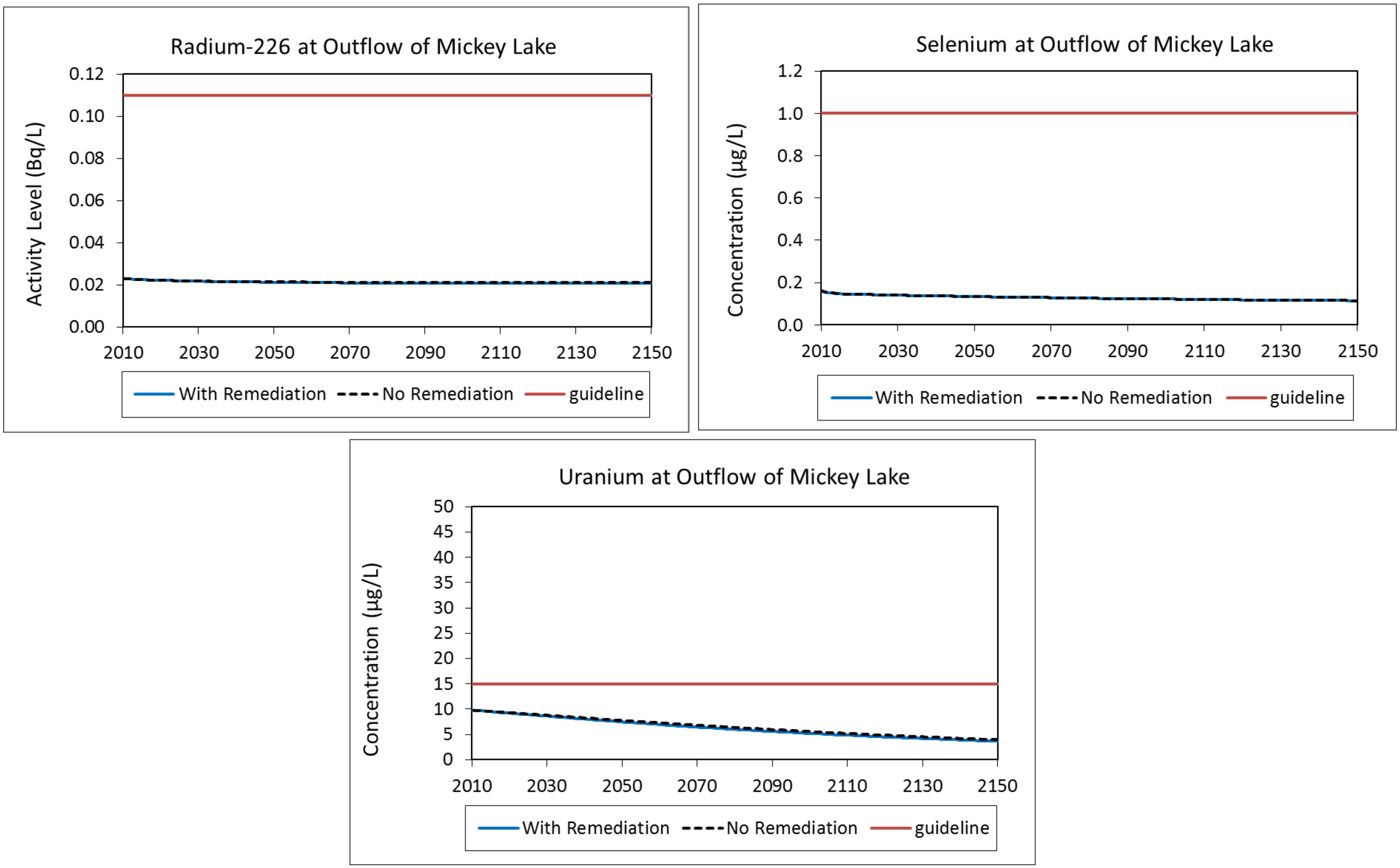


Figure 2.3-19 Ace Lake Water Quality Predictions (Backfill Pistol Lake)

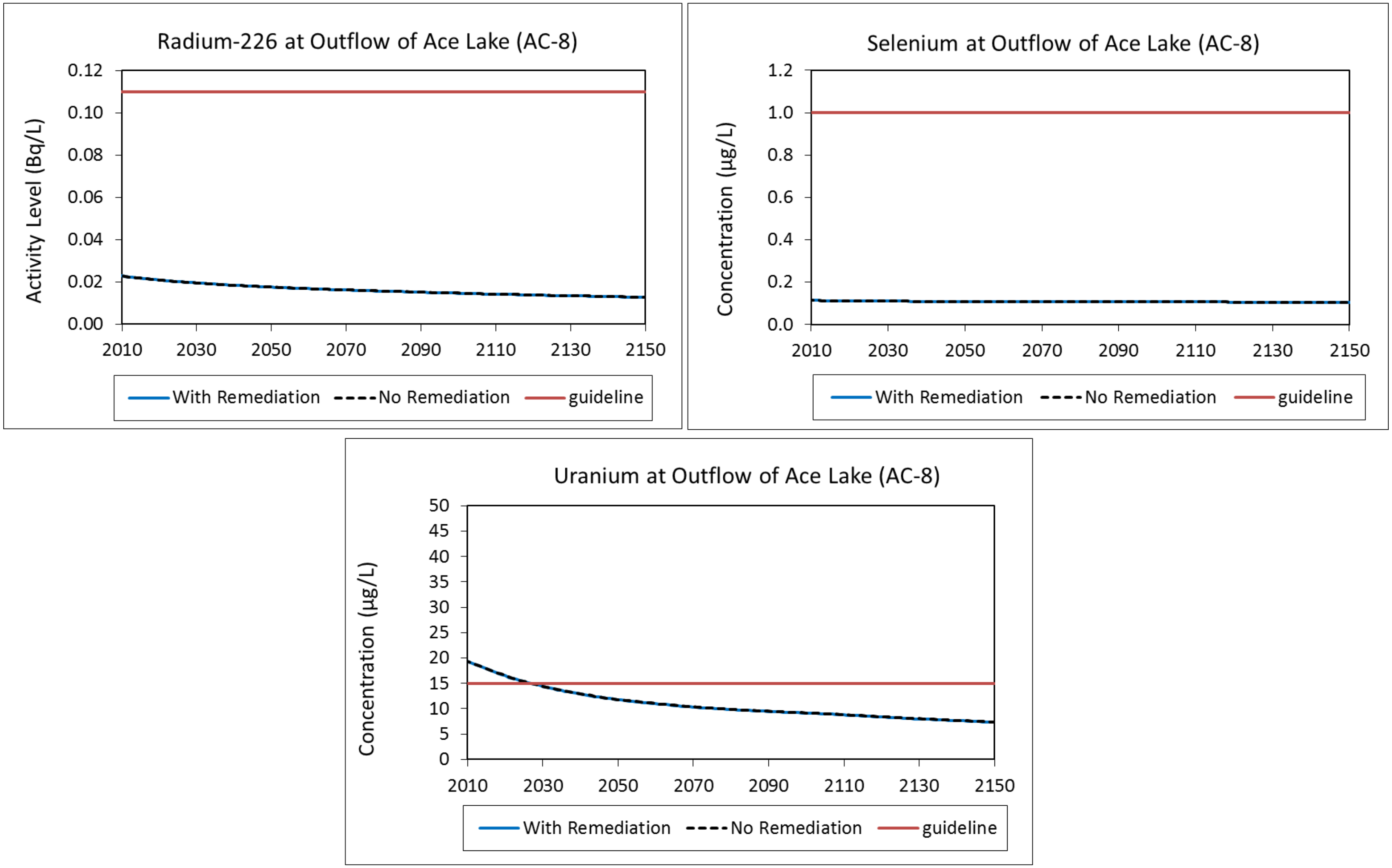


Figure 2.3-20 Summary of Outcomes in Pistol Lake (Backfill Pistol Lake)

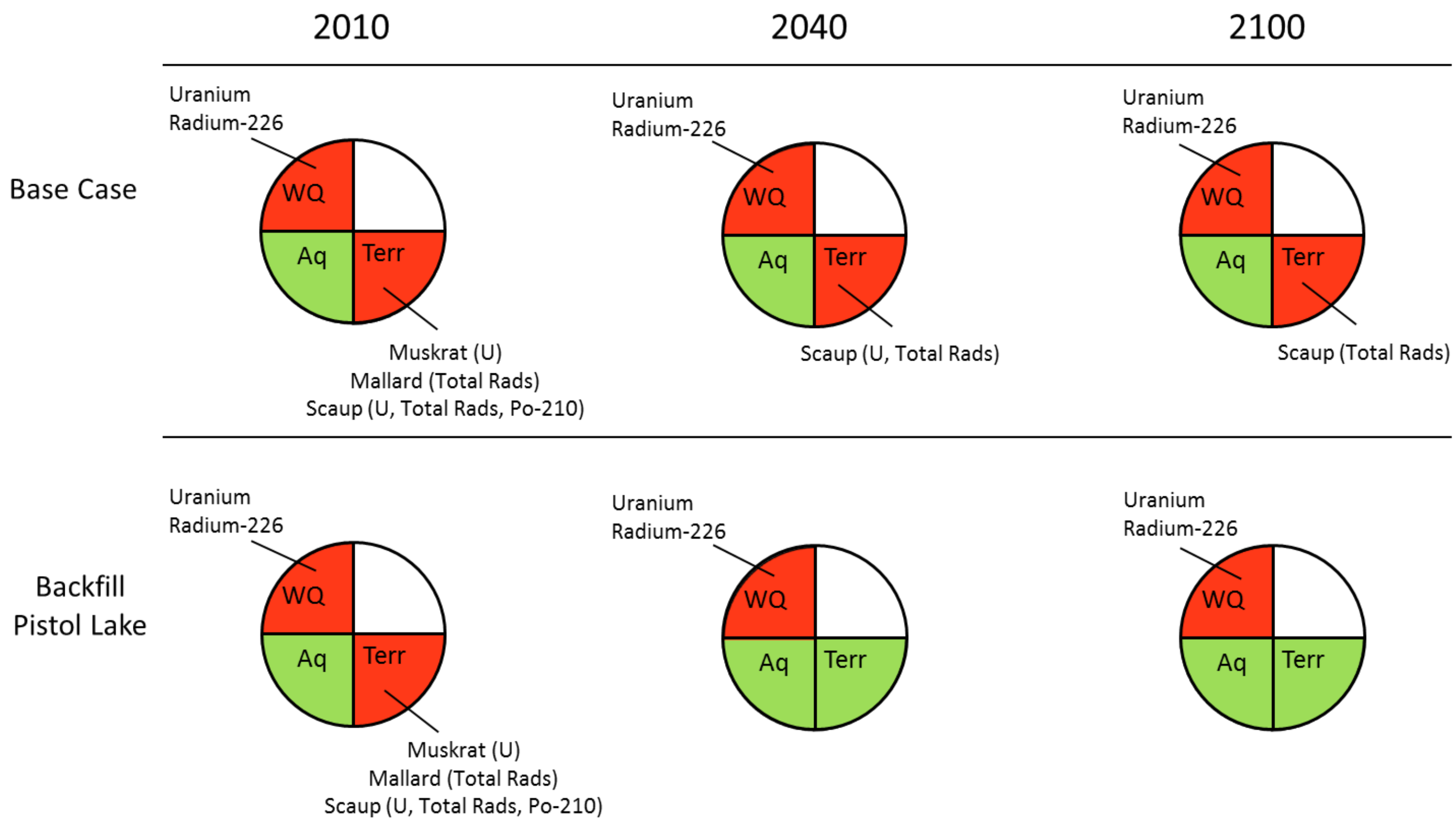
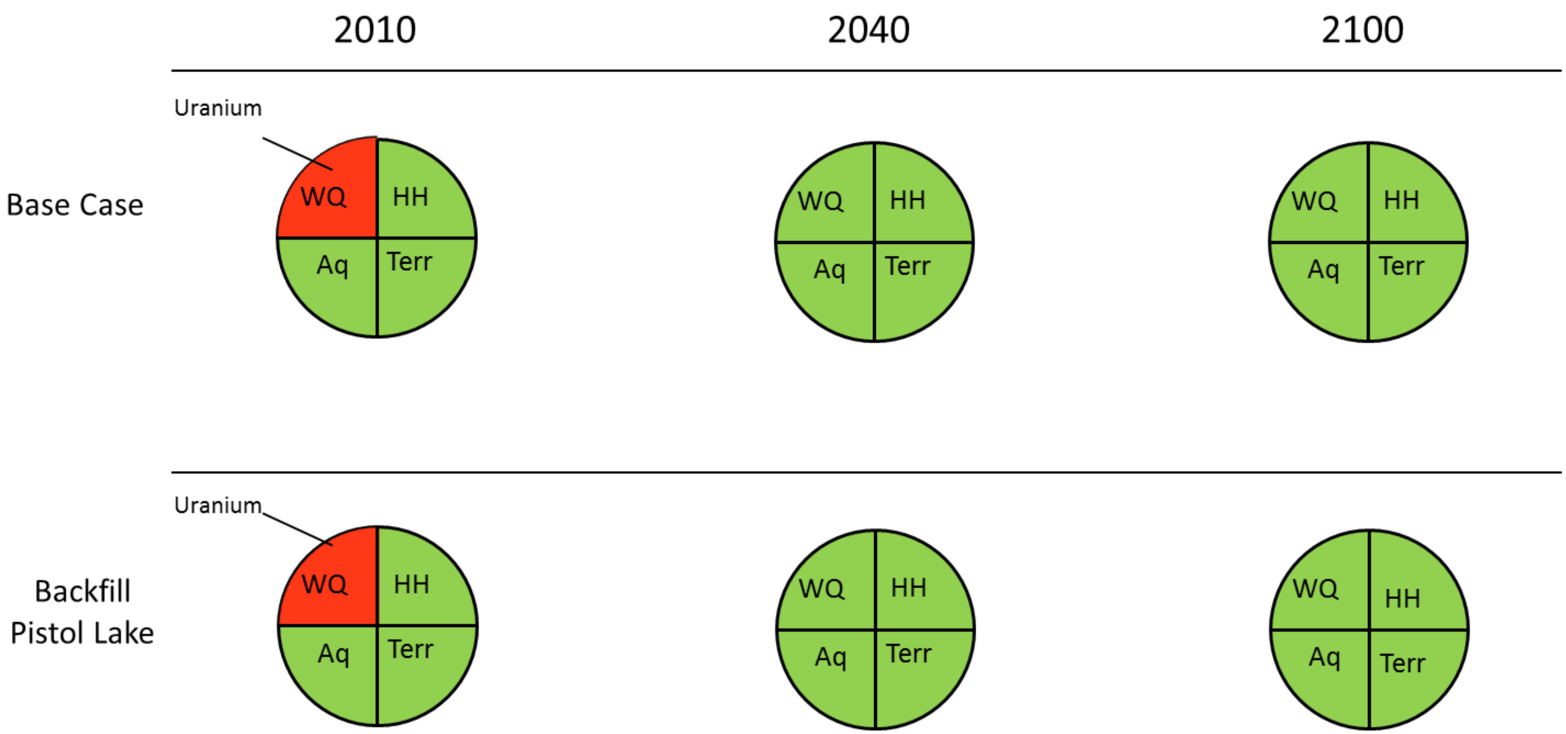


Figure 2.3-21 Summary of Outcomes in Ace Lake (Backfill Pistol Lake)



2.3.3.5 Water Treatment at Outlet of Pistol Lake

This activity involves installation of a water treatment system and associated dam structure at the outlet of Pistol Lake. The Beaverlodge Costing Report (SENES & SRK 2012) looked at long-term removal of radium-226 alone and both radium-226 and uranium. Details of these considered water treatment systems are provided in SENES & SRK (2012). The investigated system to handle both scenarios is an on-site ion exchange plant with an operating capacity of 74,200 m^3/yr over an operating period of 200 days/yr. For radium-226 removal alone, resin will be removed annually and disposed of in an on-site burial trench within the Fookes Reservoir tailings basin. If uranium removal is also occurring, the used resin generated by the operation of this system would be transported to one of Cameco's mills for uranium recovery on an annual basis. In either case, disposal of resin would likely require additional regulatory approval.

Potential effects of treating for both uranium and radium-226 at the outlet of Pistol Lake were assessed using the Beaverlodge QSM (SENES 2012a) assuming the installation of the treatment facilities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- Operating capacity of water treatment system is 74,200 m3/yr, additional water discharges downstream untreated
- System able to achieve concentrations of:
    - Radium-226: 0.11 Bq/L
    - Uranium: 10 µg/L
- It should be noted that after that 50 years of operation, either an additional investment will be required to maintain/replace the treatment facility or the load to the downstream environment will be the same as if water treatment had never occurred.

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 73% from 4.8×10^4 kBq/yr to 1.3×10^4 kBq/yr and a reduction in uranium load of 86% from 19.7 kg/yr to 2.7 kg/yr to the downstream environment. However, after 50 years of operation, either an additional investment will be required to maintain/replace the treatment facility or the load to the downstream environment will be the same as if water treatment had never occurred.

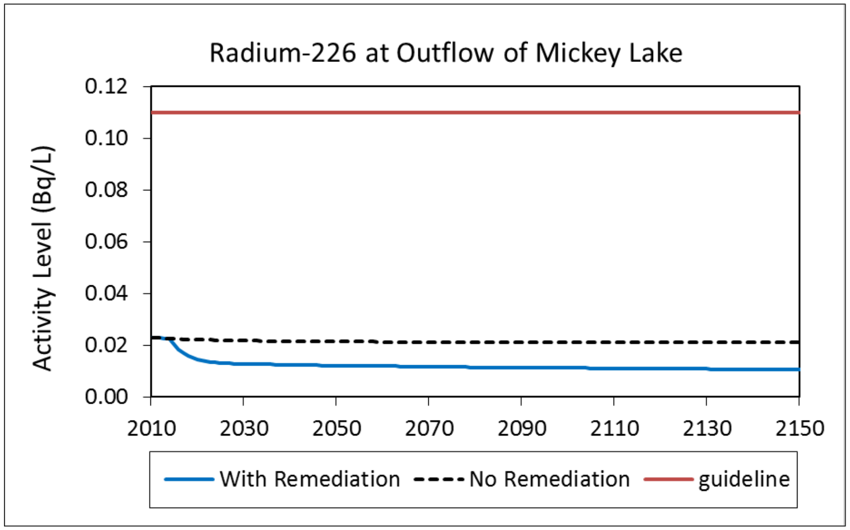
Predicted water quality in the downstream environment over the 2010-2150 period is shown in Figures 2.3-22 and 2.3-23. Water treatment at the outlet of Pistol Lake is not expected to impact water quality within Pistol Lake. Similar to the other remedial measures discussed above, significant improvements in the downstream environment (Mickey and Ace lakes) are not seen.

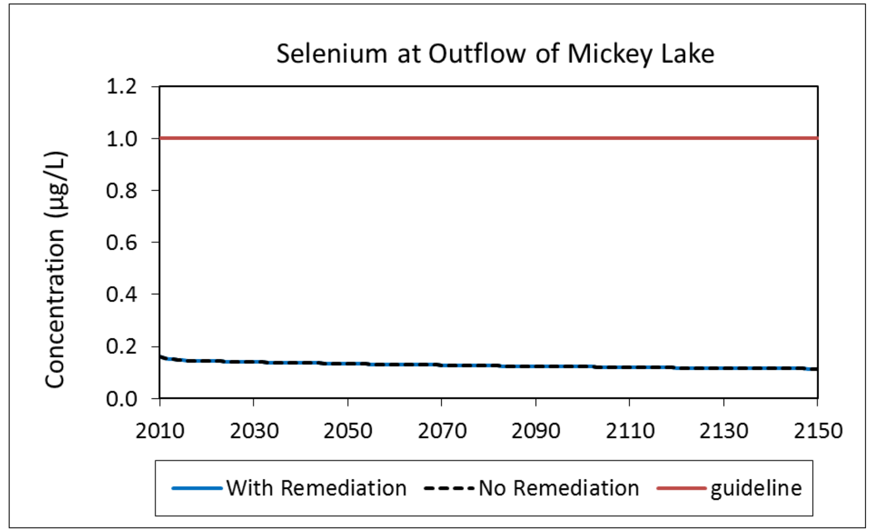
A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.3-24 for Ace Lake as compared to the base case, with no remediation. As can be seen, there are no predicted risks to ecological receptors in the Ace Lake area with or without water treatment at the outlet of Pistol Lake.

It should be noted that this remediation activity involves perpetual maintenance of the water treatment system and associated dam structure at the outlet of Pistol Lake.

Costs of installation as well as long-term operation and maintenance of the water treatment plant at the outlet of Pistol Lake were estimated by SENES & SRK (2012) to be approximately $9 and $38 million CAD for removal of radium-226 alone and both radium-226 and uranium, respectively. These costs include the NPV of annual operating and maintenance cost of $0.3 million CAD for radium-226 removal and $1.3 million CAD for removal of both radium-226 and uranium.

Figure 2.3-22 Mickey Lake Water Quality Predictions (Water Treatment at Pistol Lake Outlet)





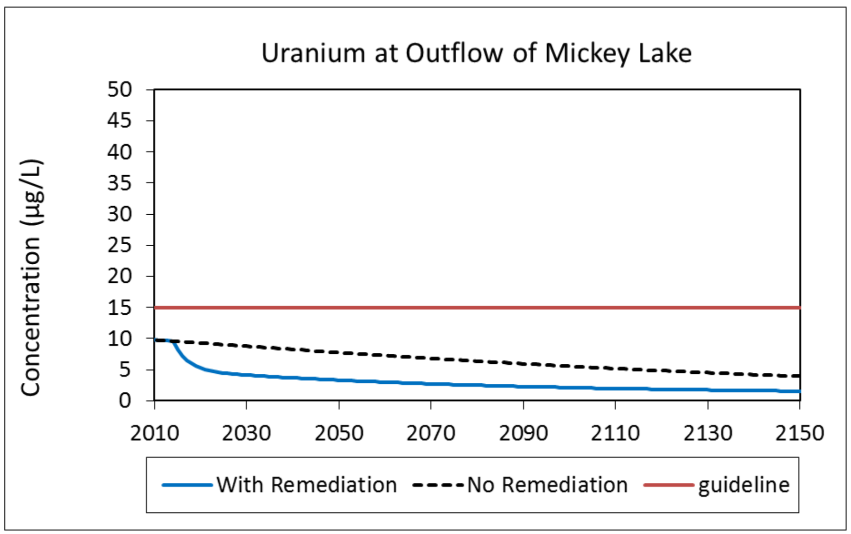


Figure 2.3-23 Ace Lake Water Quality Predictions (Water Treatment at Pistol Lake Outlet)

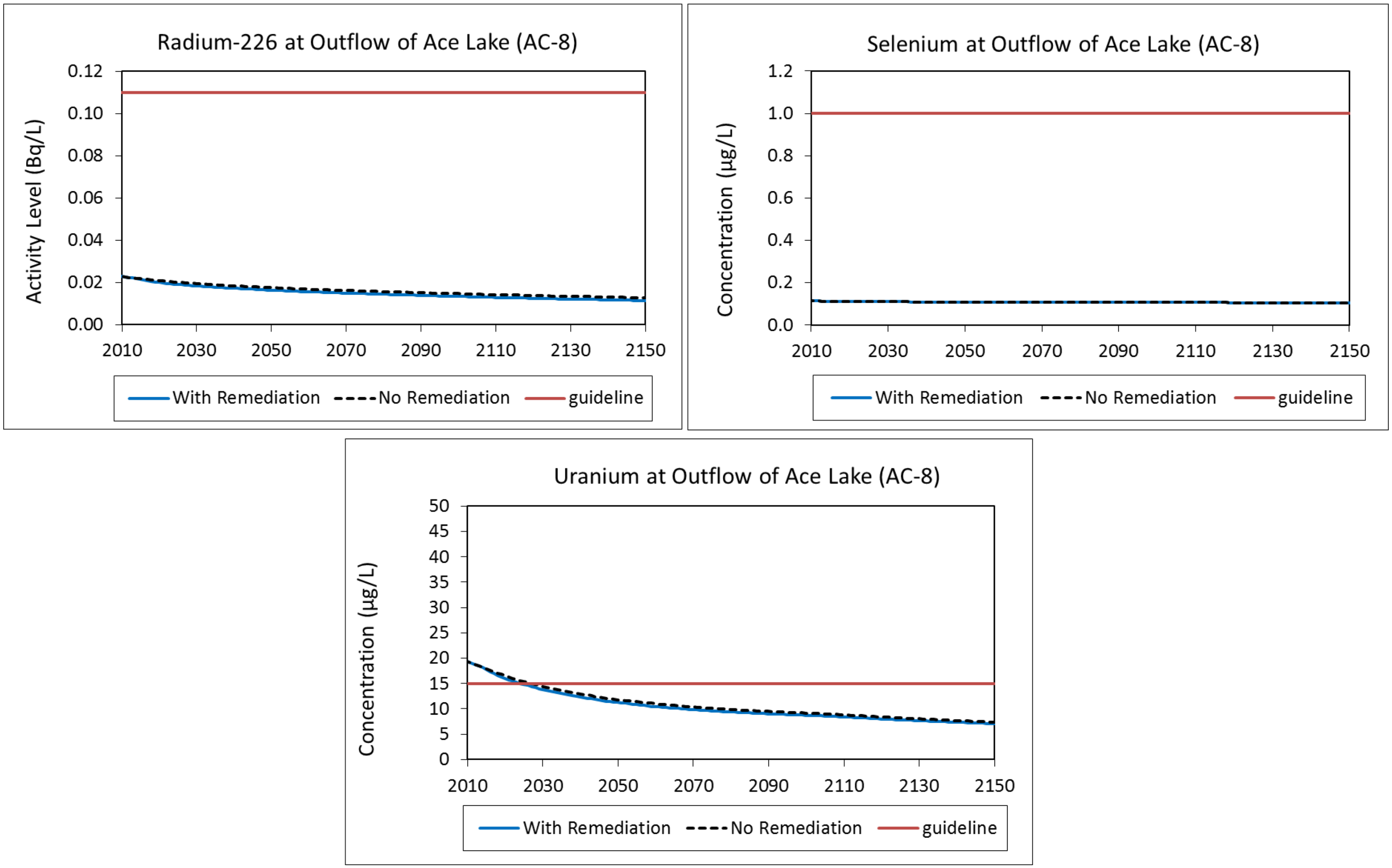
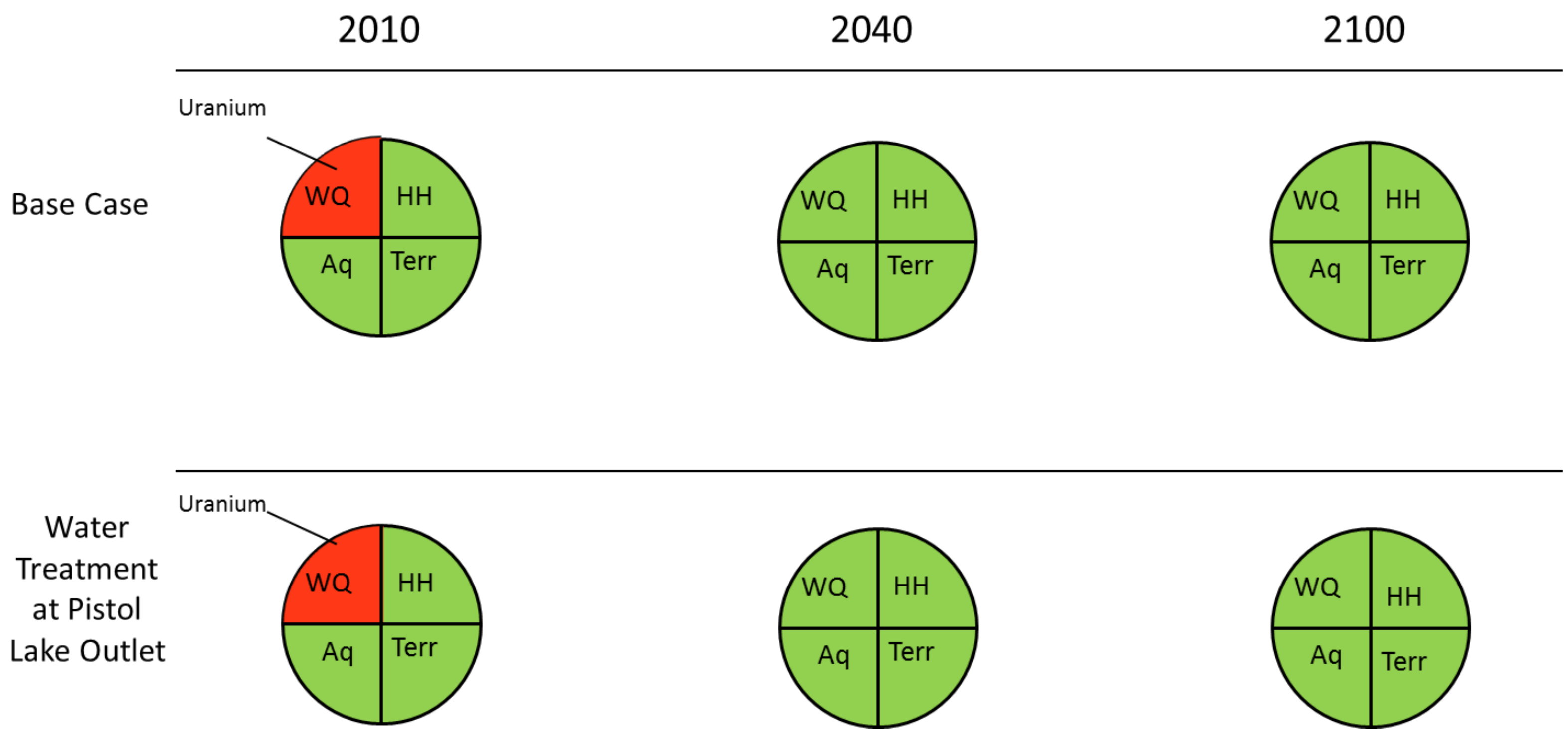


Figure 2.3-24 Summary of Outcomes in Ace Lake (Water Treatment at Pistol Lake Outlet)



2.3.3.6 Replacement of Caps on Vertical Openings

This activity involves replacing the original concrete caps on all vertical mine openings in the Hab area with engineered caps, which may consist of concrete or stainless steel. The decommissioning documentation (MacLaren Plansearch 1987) identifies nine openings in the Hab area; eight of these openings are indicated in Figure 2.3-1. It is possible that exploration work may be required to locate the remaining vertical mine opening.

It is not anticipated that this activity will result in any change to the immediate or downstream environments; however, it is included for discussion as it is considered to be good engineering practice and will improve the long-term safety of the site for people and wildlife frequenting the area. It is assumed that these engineered caps would require an assessment of condition after a period of between 75 and 100 years and more frequently following. For the calculation of future monitoring and maintenance costs it is assumed that the caps will require replacement every 100 years although this is overly conservative.

The cost of replacing these vertical mine opening caps was estimated to be approximately $70,000 (SENES & SRK 2012) for each cap based on previous experience as well as an additional cost of approximately $70,000 for mobilization, de-mobilization, site preparation and site clean-up. As well, an additional estimated cost of $100,000 may be required to locate remaining vertical openings within the Hab, Dubyna, Bolger/Verna and Lower Ace Creek areas.

2.3.3.7 Plug Identified Non-flowing Boreholes

This activity involves applying grout to all identified non-flowing boreholes in the Hab Mine area. This activity is considered to be good engineering practice as it reduces the risk that these openings might serve as conduits for mine water in the future.

Plugging non-flowing boreholes will not affect the immediate or downstream environments.

Estimated costs of plugging identified non-flowing boreholes are approximately $10,000 CAD.

2.3.4 Hab Selection of Remedial Activities

In addition to predicted changes to the environment as assessed by the Beaverlodge QSM (SENES 2012a) and estimated costs of assessed activities (SENES & SRK 2012), stakeholder feedback received during the Beaverlodge Remedial Option Workshop (ASKI, SENES & SRK 2012) can be used as additional information to help inform the remedial activity evaluation process. Outcomes from these three sources are discussed below. In addition, the costs and benefits for each of the remedial measures considered for the Hab area are summarized in Table 2.3-2. For each remedial activity expected change to exceedances, predicted reduction in loads, estimated costs as well as calculated cost per unit reduction are presented.

Table 2.3-2 Summary of Predicted Effects of Remedial Activities, Hab Area

Remedial Measure	Change to Water Quality or Human/Eco Risk?[a,b]	Reduction in Load to Downstream Environment[c]			Estimated Costs (CAD)	Cost per Unit Reduction[c]			Comments
		Ra-226 (MBq/yr)	Se (kg/yr)	U (kg/yr)		Ra-226 (CAD/kBq/yr)	Se (CAD/g/yr)	U (CAD/g/yr)	
Divert Beatrice Lake outflow around waste rock	no change to exceedances	25.5 (53%)*	-	8.8 (45%)*	$1,100,000	43*	-	125*	-effectiveness of diversion uncertain -flowpath between Beatrice Lake and Pistol Lake uncertain -predicted effect on contaminant loads downstream of Pistol Lake minimal - predicted cost assumes locally accessible borrow material, which is unlikely -requires ongoing maintenance of either dam structure or synthetic liner materials
Excavate waste rock to plug flowing boreholes and other mine openings	no change to exceedances	12.4 (26%)*	-	7.0 (35%)*	$2,200,000 plus additional cost of plugging boreholes and openings	177+*	-	316+*	-effectiveness of plugging uncertain -location of boreholes and other mine openings largely unknown -cost of project uncertain -predicted effect on contaminant loads downstream of Pistol Lake minimal
Reshape and cover waste rock pile	no change to exceedances	2.9 (6%)	-	0.7 (4%)	$2,800,000	964	-	3,836	-predicted effect on contaminant loads downstream of Pistol Lake minimal
Backfill Pistol Lake	no change to exceedances	0.2 (0.5%)	-	0.3 (1.6%)	$900,000	3,913	-	2,903	-predicted effect on contaminant loads downstream of Pistol Lake minimal
Treat water at the outlet of Pistol Lake	no change to exceedances	35 (73%)	-	17.0 (86%)	$37,800,000	1,074	-	2,224	-predicted effect on contaminant loads downstream of Pistol Lake minimal -cost of water treatment at the outlet of Pistol Lake unjustifiably high -additional regulatory licensing requirements -requires ongoing operation and maintenance of treatment system

Table 2.3-2 Summary of Predicted Effects of Remedial Activities, Hab Area (Cont'd)

Remedial Measure	Change to Water Quality or Human/Eco Risk?[a,b]	Reduction in Load to Downstream Environment[c]			Estimated Costs (CAD)	Cost per Unit Reduction[c]			Comments
		Ra-226 (MBq/yr)	Se (kg/yr)	U (kg/yr)		Ra-226 (CAD/kBq/yr)	Se (CAD/g/yr)	U (CAD/g/yr)	
Replace caps on vertical mine openings	no change to exceedances	-	-	-	$700,000 plus the additional cost to locate the remaining opening	-	-	-	-good engineering practice -reduces future hazard to those using the site -no predicted effect on contaminant loads
Plug identified non-flowing boreholes	no change to exceedances	-	-	-	$10,000	-	-	-	-no effect on contaminant loads -good engineering practice

Notes:

[a] for the base case scenario (no remediation), there is no predicted risk to any assessed ecological receptors in Ace Lake throughout the modeled period.

[b] human receptors assessed at Ace Lake but not Pistol Lake

[c] load reductions estimated over the first 50 years after implementation

* Actual benefits and associated costs per unit reduction may vary greatly from these values due to the uncertainty regarding effectiveness of implementing these remedial activities

The effectiveness of the diversion of Beatrice Lake outflow to avoid contact with the waste rock pile is uncertain. It is unclear where water entering the waste rock exists and what the input is to Pistol Lake immediately downstream. In addition there is little predicted benefit to the downstream environment even if moderate project success is assumed. Pistol Lake is a very small (1.2 ha) non-fish bearing waterbody with limited ecological value. Any benefit from this activity would be limited to Pistol Lake as the flows are not significant enough to have any noticeable downstream effect. This activity was included in a number of remedial measure scenarios evaluated at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). In general, workshop participants did not object to the stream diversion, however, many raised concerns about the considerable unknowns regarding the hydrogeology of the region as well as the fact that this option would likely involve construction activities such as channeling directly over the crown pillar. It was also noted that the diversions discussed would require ongoing maintenance of either a dam structure and/or synthetic liner material. This remedial activity has the most favorable estimated cost per unit reduction of all activities examined for the Hab Mine site; however, due to the uncertainty regarding success of this remedial activity, and the uncertainty regarding assumptions used in the cost estimate, the actual unit costs per unit reduction may be significantly higher.

Reshaping and cover of the Hab waste rock pile is seen to have little benefit to the immediate and downstream environment. This activity was also discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). During discussions it was clear that many stakeholders felt that this activity is not justified due to the minimal benefit achieved; a position justified by the relatively high cost per unit reduction seen.

As with stream flow diversion, there is uncertainty around the success of plugging boreholes and other flowing mine openings in the Hab Mine area. For this reason, it was not discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). Even assuming reasonably good reductions in flow from the underground mine are achievable, significant benefit of this activity is not predicted in the downstream environment.

Backfilling Pistol Lake and water treatment at the outlet of Pistol Lake both show very little benefit to the downstream environment, therefore were not discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). It should be noted, however, that many stakeholders expressed concerns regarding the large amount of borrow material required for some of the options discussed and the lack of known borrow material in the area. The estimated cost of water treatment at the outlet of Pistol Lake is considered by Cameco to be unjustifiably high given the lack of benefit achieved downstream.

Replacing the caps on the vertical mine openings in the area is not expected to influence water quality in the area, however, it is considered to be good engineering practice as it reduces the potential for cap failure in the future. Similarly, plugging non-flowing boreholes in the area will not benefit the environment but is considered to be a good engineering practice. These activities will also prepare the site for transfer into the provincial IC Program.

Based on the evaluation presented above, the recommended course of action developed by Cameco for the Hab site is to replace the caps on all vertical mine openings, plug identified non-flowing boreholes and continue to monitor the area to ensure that recovery is progressing as expected. The other considered activities are not recommended due primarily to the uncertainty regarding achievable reduction in loads to Pistol Lake as well as the fact that little effect is predicted on the downstream environment even if some success in this regard is assumed.

2.4 Bolger/Verna Mine Site

The Bolger/Verna Mine site is located within the Ace Creek Watershed. The main water bodies in the Bolger/Verna area are Verna Lake which receives water from upstream Zora Lake. Fresh water flows into Zora Lake from upstream Moran Lake. Water exiting Verna Lake flows immediately into Ace Lake. The Bolger/Verna Mine area is shown in Figure 2.4-1.

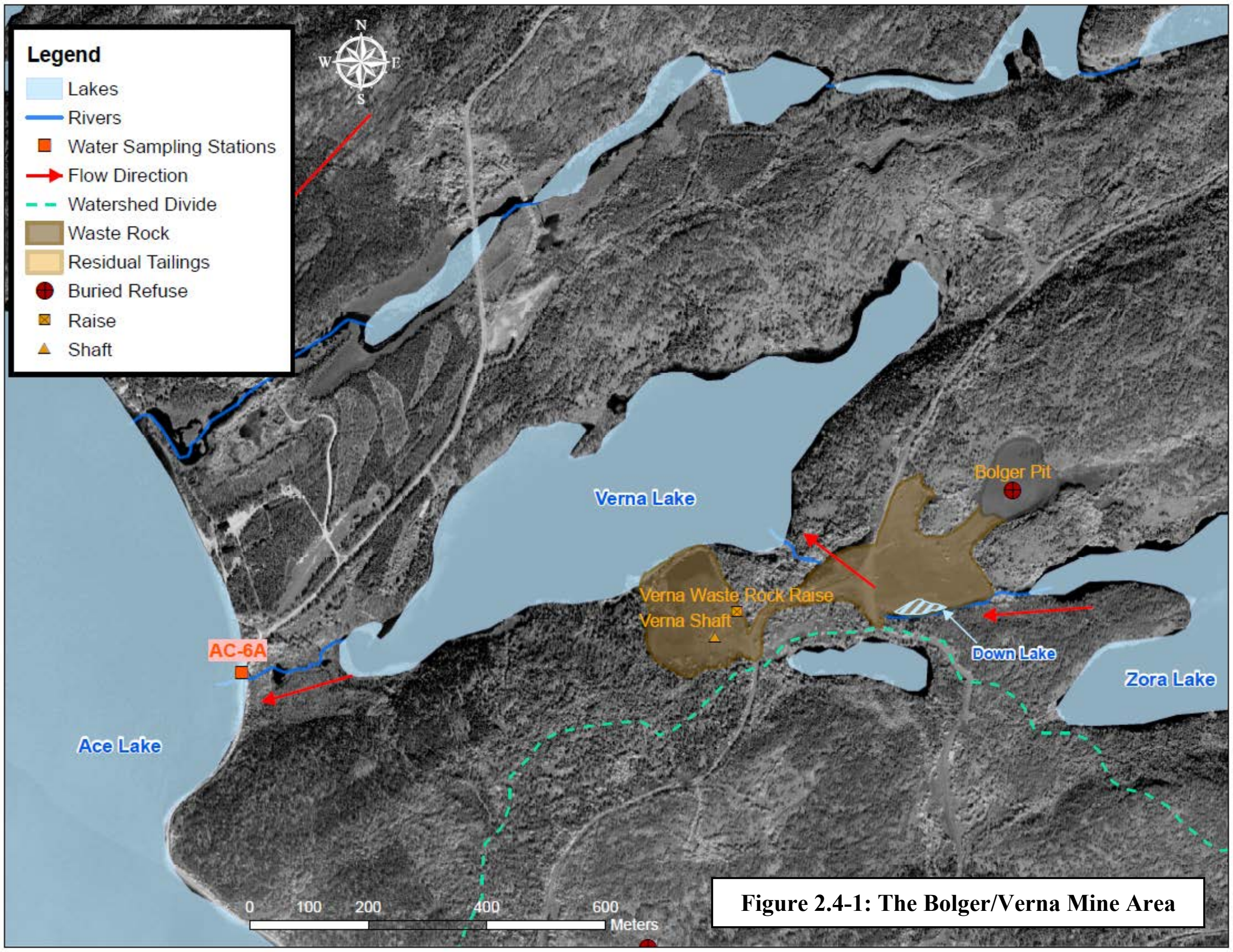


Figure 2.4-1: The Bolger/Verna Mine Area

2.4.1 Bolger/Verna Site Features

At the Bolger/Verna site mine waste rock from the open pit mine was cast into the area west of the pit and extends across a valley through which Zora Creek flows (see Figure 2.4-1). Mine waste rock from development of the Verna raise and shaft was deposited on the shoreline of Verna Lake. The Bolger mine was operated intermittently between 1959 and 1980 and minewater was discharged untreated to Verna Lake during the early years of operation. The Fay-Verna underground mine was operational until 1982. Following closure, refuse (garbage) from the decommissioning activities was buried in the Bolger pit.

A tracer investigation undertaken to verify that Zora Creek flow passes through the waste rock pile into Verna Lake did not prove successful. Temperature measurements on the outflow from the pile suggest that there may be ice lenses within the pile that affect the flow path of Zora Creek. In addition, water periodically ponds upstream of the waste rock pile, supporting the theory that ice lenses may intermittently block drainage through the pile. This ponded water is referred to as Down Lake and is shown in Figure 2.4-1. Attempts to measure the flow in Verna Creek have also not provided sufficient information to characterize/quantify chemical loadings from Verna Lake. A water quality monitoring station has recently been established on Verna Creek at station AC-6A; however, monitoring over the last number of years indicates that this stream is ephemeral in nature as it has not always been possible to obtain a sample as the creek bed has often been found to be dry.

2.4.2 Bolger/Verna Assessment of Potential Risks

In order to select remedial measures, the potential risks that various features within the Bolger/Verna site may pose to the environment and members of the public accessing the site were assessed. Aspects examined included mining geotechnical; surface water; contaminated substrate; air, radon and gamma; terrestrial and aquatic vegetation; and risk communication. When determining a relative risk rating for each site element likelihood of the event occurring as well as the consequence of that event were considered. The resulting relative risk estimates for the Bolger/Verna Mine site are shown in Table 2.4-1.

Table 2.4-1 Summary of Estimated Risks, Bolger/Verna Area

Aspect	Specific Location	Site Element	Current Risk Registry		Risk Endpoint		References
			Event	Effect	Environmental Risk	Public Health and Safety Risk	
Mining Geotechnical	**Verna Site**	**Crown Pillar**	Pillar failure (collapse)	Formation of sinkholes creating a falling hazard for wildlife and human	L	L	Screening Level Risk Assessment, Cameco 2010b.
		Waste Rock Pile	Slope instability and failure	Falling hazard for wildlife and human	L	L	Waste Rock Stability Assessments: Former Eldorado Beaverlodge Sites, SRK 2010
		Sealed Openings to Surface	Cap fail (4 raises)	Formation of opening (vertical hole) to underground workings creating a falling hazard for wildlife and human	M	M	Departure With Dignity: Decommissioning of the Beaverlodge Mine/Mill. MacLaren Plansearch 1987.
			Adit opening (72 Zone and Verna)	Open access to workings	L	L	Departure With Dignity: Decommissioning of the Beaverlodge Mine/Mill. MacLaren Plansearch 1987.
	Bolger Site	**Pit Walls**	Walls failure	Hazardous situation for wildlife and human	ML	ML	Departure With Dignity: Decommissioning of the Beaverlodge Mine/Mill. MacLaren Plansearch 1987.
			Falling Hazard	Falling event for wildlife and human	ML	ML	Screening Level Risk Assessment, Cameco 2010b.
	General	**Demolition Material**	Erosion causing exposure of material	Safety concern, e.g. falling hazards	L	ML	Screening Level Risk Assessment, Cameco 2010b.
			Slumping	Open hole and falling hazard for human and wildlife	L	L	Screening Level Risk Assessment, Cameco 2010b.
Surface Water (incl. Flowing Drillholes)	**Verna Site**	**Waste Rock Pile**	Surface runoff and precipitation infiltration through the waste rock into Verna Lake	Impact on Verna Lake water quality	ML	L	Beaverlodge Quantitative Site Model. SENES 2012a.
			Leaching of mine slimes deposited in waste rock to Verna Lake	Impact on Verna Lake water quality	ML	L	Beaverlodge Quantitative Site Model. SENES 2012a.
	Bolger Site	**Waste Rock Pile**	Surface runoff and precipitation infiltration through the waste rock into Zora Creek	Impact on Zora Creek water quality	ML	L	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009. Results of Field Investigations in the Areas of the Decommissioned Fay-Verna, Hab and Dubyna Mines, Golder 2010. Ace Creek Characterization Report. Cameco 2009. Aquatic Macrophyte Sampling Program. CanNorth 2011a.
	General	**Demolition Material**	Erosion of demolition material and discharges to Zora Creek/Verna Lake	Impact on Zora Creek/Verna Lake water quality	L	L	Screening Level Risk Assessment, Cameco 2010b.
	Zora Lake	**Zora Outflow**	Channel flowing through waste rock to Verna Lake	Impact on Verna Lake water quality	M	L	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009. Results of Field Investigations in the Areas of the Decommissioned Fay-Verna, Hab and Dubyna Mines, Golder 2010. Ace Creek Characterization Report. Cameco 2009. Aquatic Macrophyte Sampling Program. CanNorth 2011a.

Table 2.4-1 Summary of Estimated Risks, Bolger/Verna Area (Cont'd)

Aspect	Specific Location	Site Element	Current Risk Registry		Risk Endpoint		References
			Event	Effect	Environmental Risk	Public Health and Safety Risk	
Contaminated Substrate	**Verna Lake**	**Substrate**	Accumulation of contaminants in sediment	Impact on Verna Lake water quality	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009. Deep Basin Sediment Study. CanNorth 2012. Aquatic Macrophyte Sampling Program. CanNorth 2011a. Uranium Deposits of the Athabasca Region. Saskatchewan Mineral Resources. Beck 1969.
	Zora Lake			Impact on Zora Lake water quality	**L**	**L**	
Air, Radon and Gamma	**General**	**Waste Rock**	Dusting of waste rock and release of airborne contaminants	Inhalation exposure for wildlife and human	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
			Radon release from exposed rock	Prolonged exposure for wildlife and human	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
			Gamma exposure from waste rock	Prolonged gamma exposure for wildlife and human	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
		Pit Walls	Gamma exposure from pit walls	Prolonged gamma exposure for wildlife and human	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
Terrestrial and Aquatic Vegetation	**General**	**Terrestrial Vegetation**	Release of COPC to air	Potential uptake of contaminants in vegetation and impact to VECs	**L**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Country Foods Survey. SENES 2012b. Draft.
		Aquatic Vegetation	Leaching of COPC to water	Potential uptake of contaminants in vegetation and impact to VECs	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Aquatic Macrophyte Sampling Program. CanNorth 2011a. Country Foods Survey. SENES 2012b. Draft.
Risk Communication	**General**	**-**	Public notification of any site risk	If not done in a timely manner may cause public safety risk	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.

As can be seen within Table 2.4-1, potential events which were estimated to pose the greatest risk to the environment and public accessing the site include failure of caps on vertical mine openings and water flowing through the Bolger waste rock pile to Verna Lake; remedial measures examined within the following section are focused on these features and potential events. It should be noted that none of the risks from this site are ranked 'high'.

2.4.3 Bolger/Verna Assessment of Remedial Activities

Potential remedial measures considered based on identified risks within the Bolger/Verna Mine site and/or to meet the standard of good engineering practice:

- Divert Zora Lake outflow to prevent contact with waste rock
- Reshape and cover waste rock piles
- Place cover on Verna Lake sediments
- Treat water at the outlet of Verna Lake for U removal
- Replace caps on vertical openings
- Plug identified boreholes

Each of these activities will be discussed in the following sections.

2.4.3.1 Zora Lake Outflow Diversion

Three stream diversion scenarios were considered for this site. These stream diversions all involve activities to eliminate contact of Zora Lake discharge with waste rock between Zora Lake and Verna Lake. Conceptual design of these diversions is discussed in SRK (2011). The first diversion scheme involves channeling an unlined path through the waste rock pile to allow flow between Down and Verna lakes without contact with the waste rock. The second design includes filling in Down Lake to allow an elevated, HDPE lined channel to be constructed through the former Down Lake area and the waste rock pile to Verna Lake. The last design involves construction of a dam at the outlet of Zora Lake and excavation of a new channel across the waste rock pile on the north site of the Down Lake area.

Potential change to environmental conditions based on these stream diversions was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes. Assumptions which were made in order to predict the effects of this diversion are:

- It was assumed that these diversions are able to successfully eliminate 50% of the load from the Bolger waste rock pile by re-routing Zora Lake outflow to avoid contact with the Bolger/Verna area waste rock piles. While likely much more than 50% of the Zora Creek flow can be successfully diverted, a 50% reduction was assumed to account for uncertainties regarding breakdown of total load from the waste rock into components from Zora Creek flow and load due to infiltration of precipitation.

- It was also assumed that none of the water flowing from Zora Creek accesses the underground mine workings; hence, it was considered that this activity does not affect any potential flow into or out of the underground workings.

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 22% from $2.9x10^4$ kBq/yr to $2.3x10^4$ kBq/yr and a reduction in uranium load of 37% from 65 kg/yr to 41 kg/yr to the downstream environment.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.4-2 and 2.4-3. As can be seen, there is a substantial decrease in the uranium levels and a reasonable decrease in the radium-226 levels in the water column of Verna Lake due to this activity. However, due to the relatively low flows from the Verna sub-watershed, there is very little benefit seen downstream in Ace Lake as a result of this activity. It should be noted that water quality in Ace Lake without any remedial activities is predicted to be below the applicable guidelines with the exception of uranium in the first few years. It is expected that this activity could cause a short-term disturbance in the area, remobilizing constituents within the waste rock which could cause decreased water quality in Verna Lake in the initial years; the QSM does not attempt to model this initial disturbance.

A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.4-4 and 2.4-5 for Verna and Ace lakes as compared to the base case, with no remediation. As can be seen, implementation of this stream flow diversion has no effect on any predicted exceedances in Ace Lake but is expected to reduce the risk to scaup in Verna Lake. Risks to receptors utilizing Ace Lake were predicted to be below the applicable SI benchmarks with and without this stream diversion.

Costs of these three stream diversions were estimated by SRK (2011) and further discussed in SENES & SRK (2012) to be between approximately $1.7 and $1.8 million CAD each.

Figure 2.4-2 Verna Lake Water Quality Predictions (Divert Zora Lake Outflow)

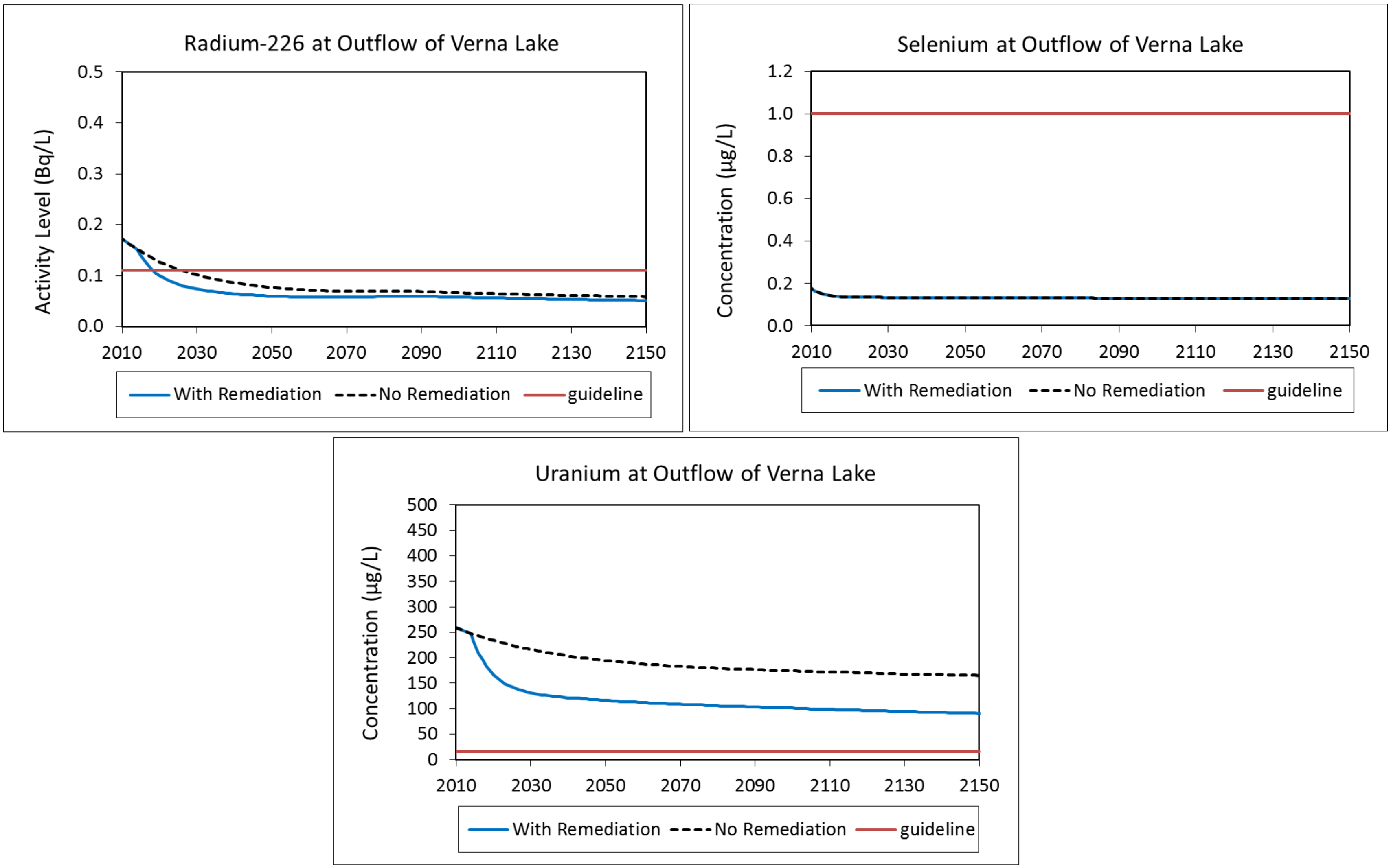


Figure 2.4-3 Ace Lake Water Quality Predictions (Divert Zora Lake Outflow)

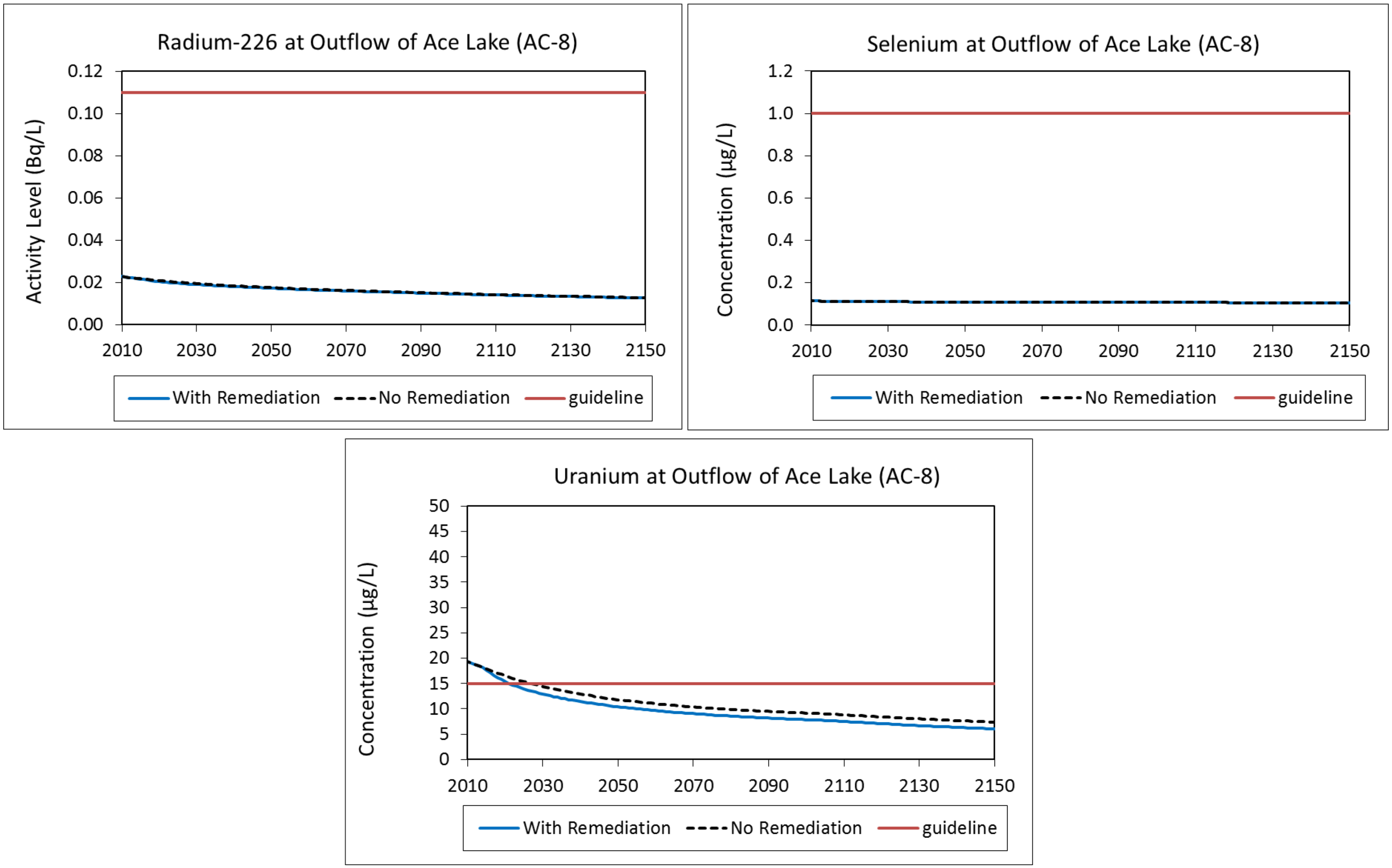


Figure 2.4-4 Summary of Outcomes in Verna Lake (Divert Zora Lake Outflow)

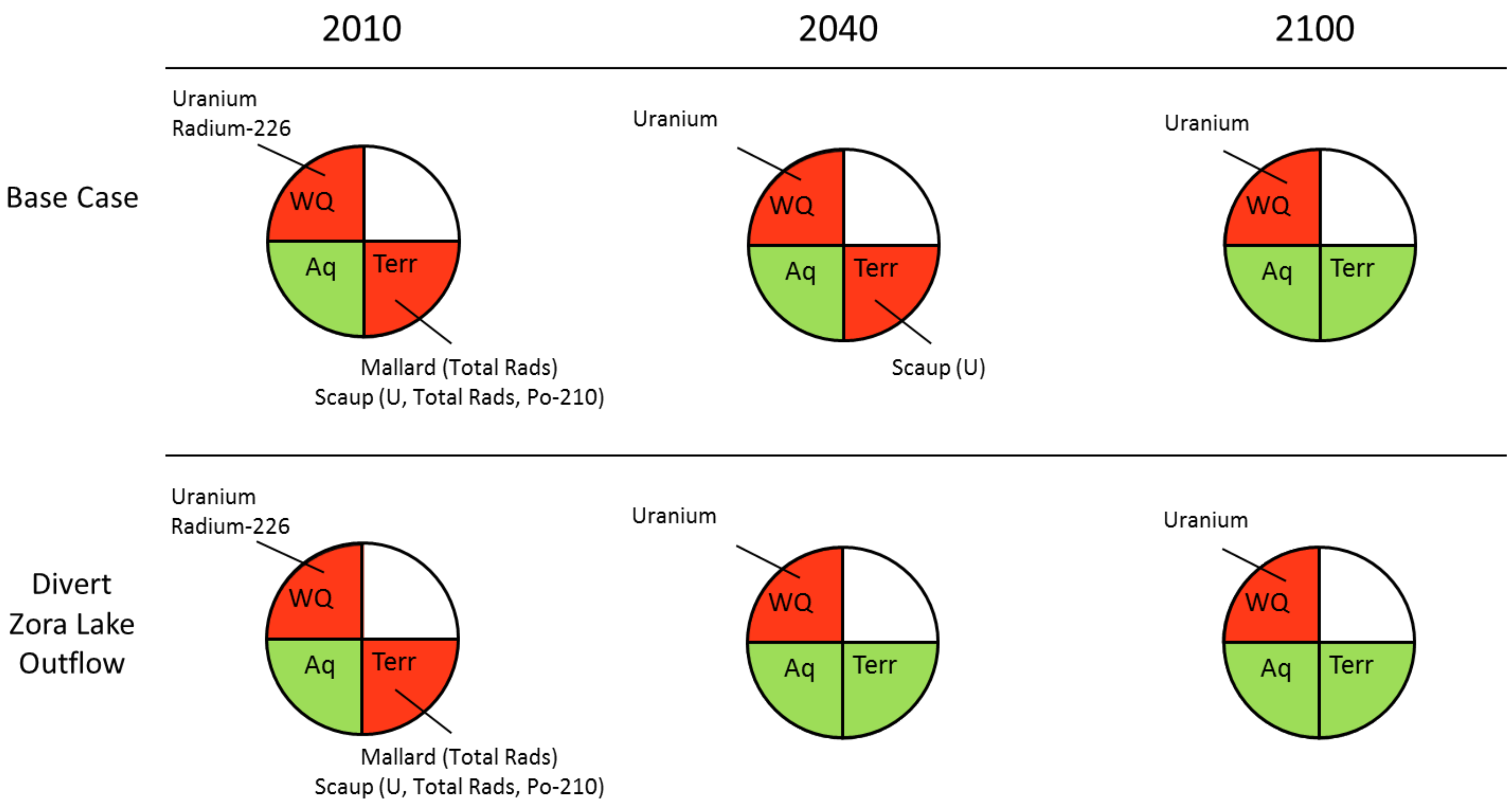
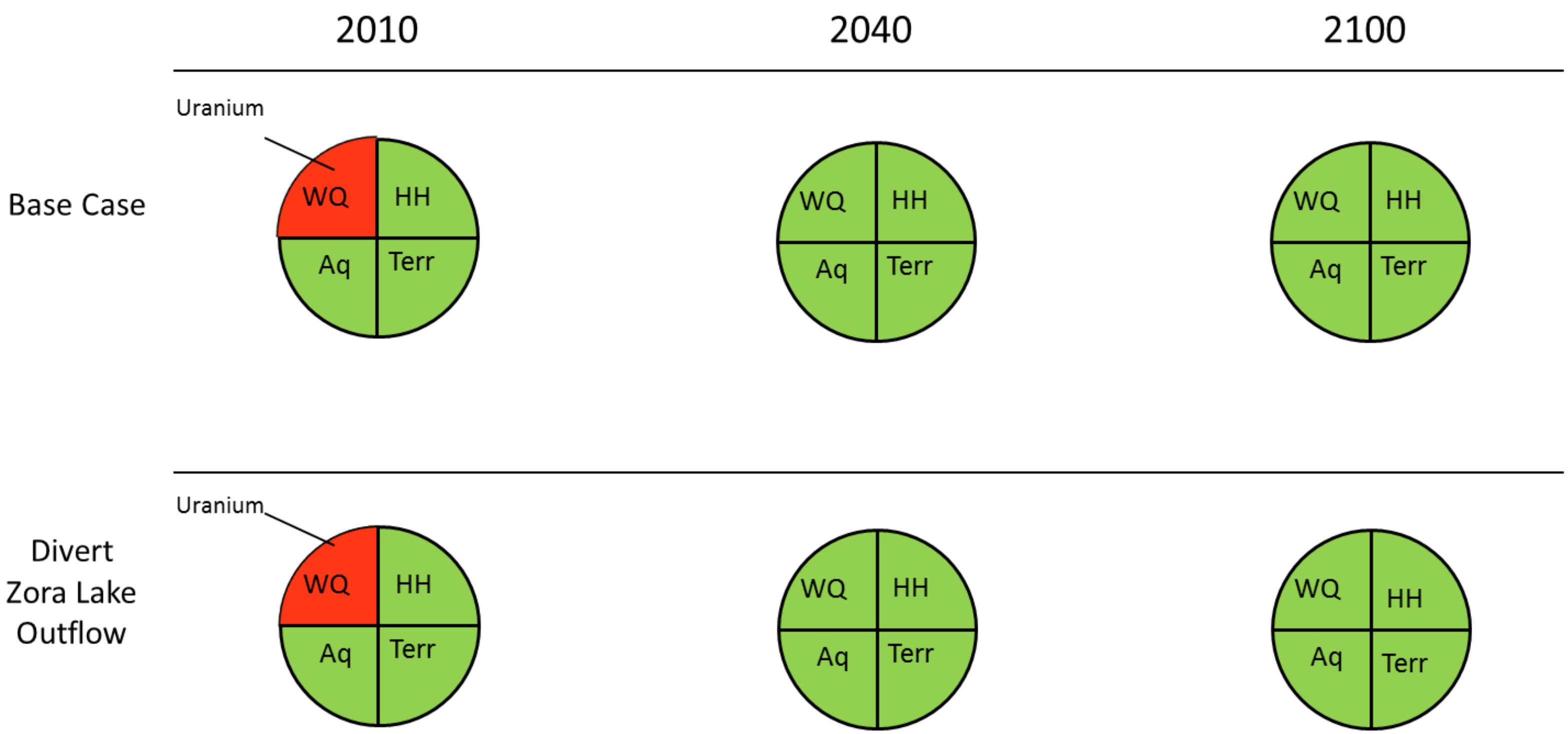


Figure 2.4-5 Summary of Outcomes in Ace Lake (Divert Zora Lake Outflow)



2.4.3.2 Reshape and Cover Bolger/Verna Waste Rock Piles

This remedial measure involves re-contouring waste rock in the Bolger/Verna area to better fit the surrounding landscape and then covering the piles with either a sand layer or by a synthetic liner (such as HDPE).

Potential change to environmental conditions based on reshaping and covering the waste rock piles in the Bolger/Verna area was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- As discussed in SENES & SRK (2012), with proper installation of a geo-synthetic liner such as the one discussed in this section, the percolation rates in the waste rock may be reduced to ~5% from 39%. The reduction in percolation through the waste rock pile is predicted to be much less with a sand cover, however, this option was assessed assuming the best case scenario.
- The annual precipitation rate for the region and base case percolation rate for the waste rock pile are discussed in SENES (2012) and were assumed to be 273 mm/a and 39%, respectively.

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 2% and a reduction in uranium load of 3% to the downstream environment.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.4-6 and 2.4-7. Almost no change to the predicted water quality is seen in either Verna or Ace lakes as a result of this activity. It should be noted that water quality in Ace Lake without any remedial activities is predicted to be below the applicable guidelines with the exception of uranium in the first few years. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.4-8 and 2.4-9 for Verna and Ace lakes as compared to the base case, with no remediation. As can be seen, implementation of this remedial measure does not change the predicted exceedances in either Verna or Ace lakes. Risks to receptors utilizing Ace Lake were predicted to be below the applicable SI benchmarks with and without the application of this waste rock cover. The results presented are for application of a geo-synthetic liner and if a sand cover is selected instead, the predicted benefit of this activity would be even less.

Costs of covering the Bolger/Verna waste rock piles were estimated by SENES & SRK (2012) to be between approximately $2.9 and $6.2 million CAD for sand and geo-synthetic covers, respectively. These estimated costs include the net present value (NPV) of a $10,000 CAD per year maintenance expense.

Figure 2.4-6 Verna Lake Water Quality Predictions (Reshape and Cover Bolger/Verna Waste Rock)

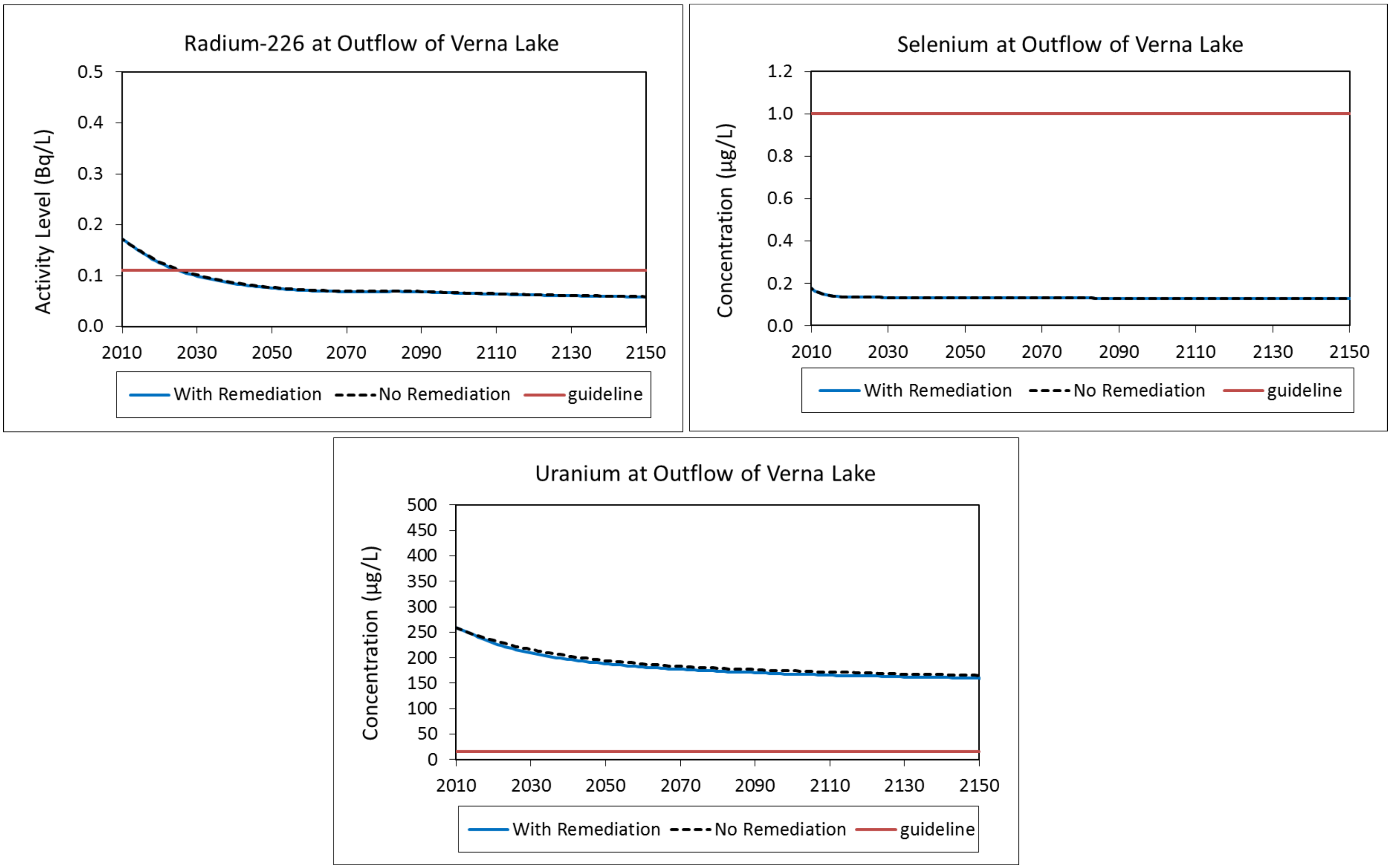


Figure 2.4-7 Ace Lake Water Quality Predictions (Reshape and Cover Bolger/Verna Waste Rock)

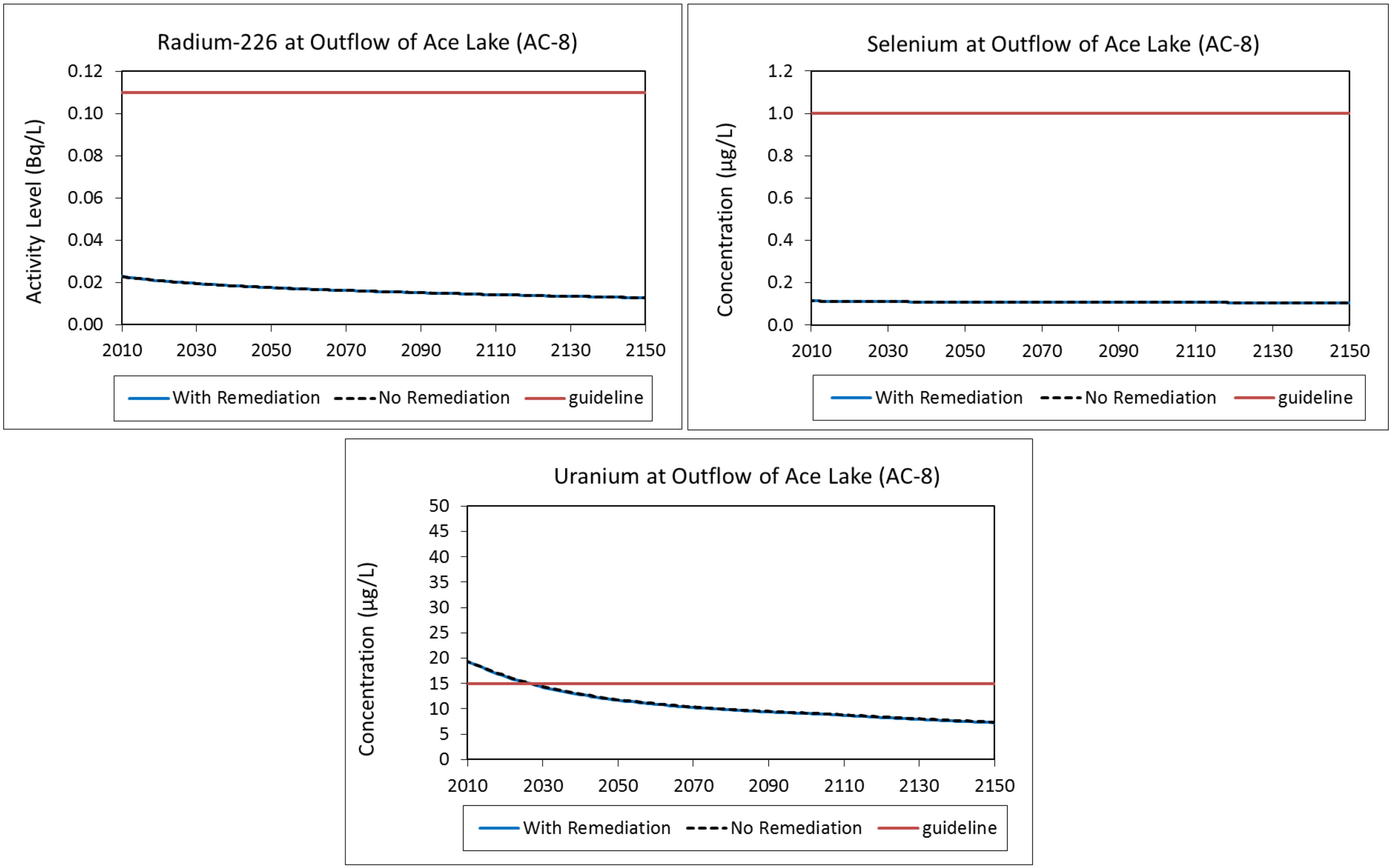


Figure 2.4-8 Summary of Outcomes in Verna Lake (Reshape and Cover Bolger/Verna Waste Rock)

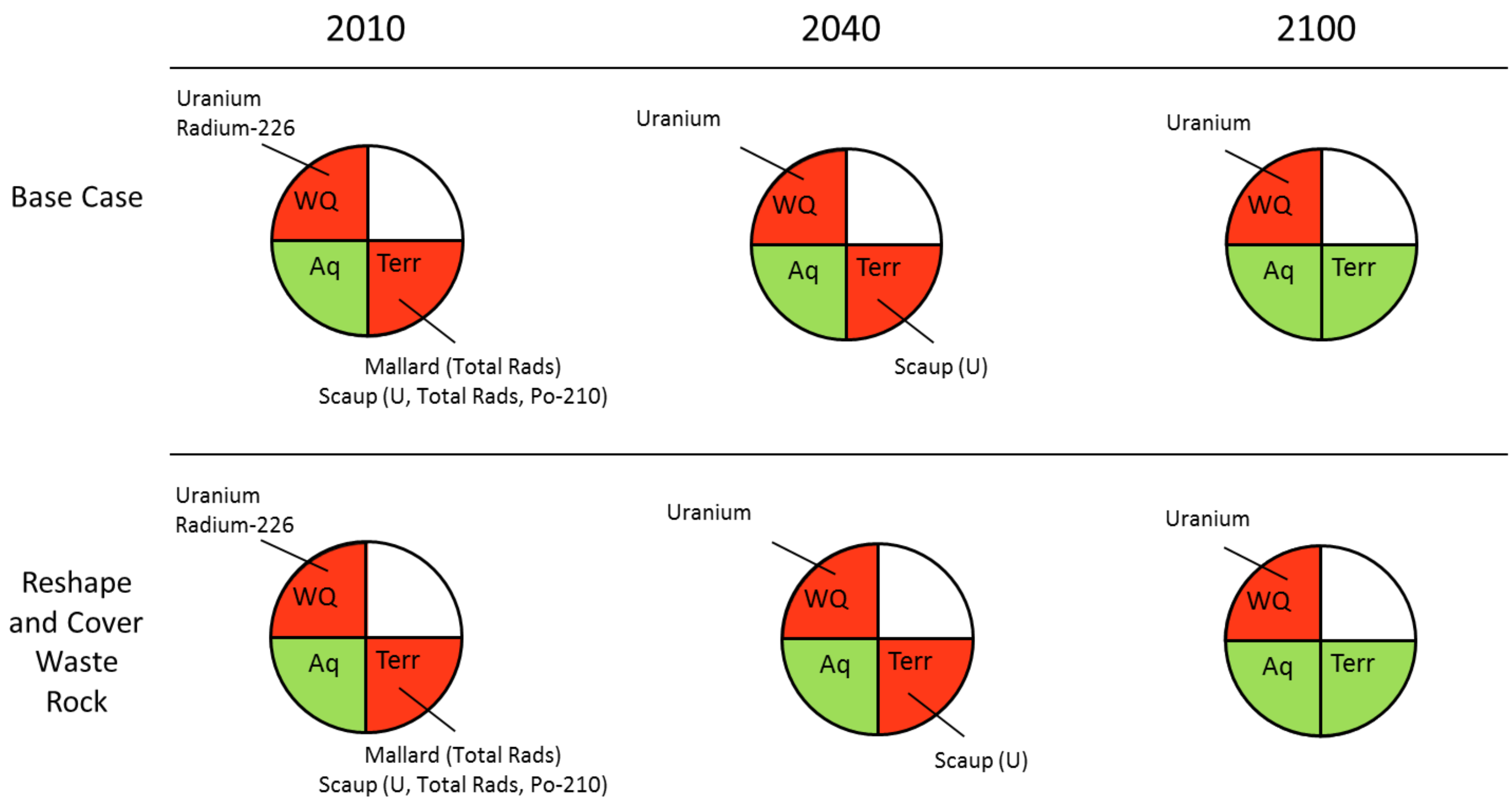
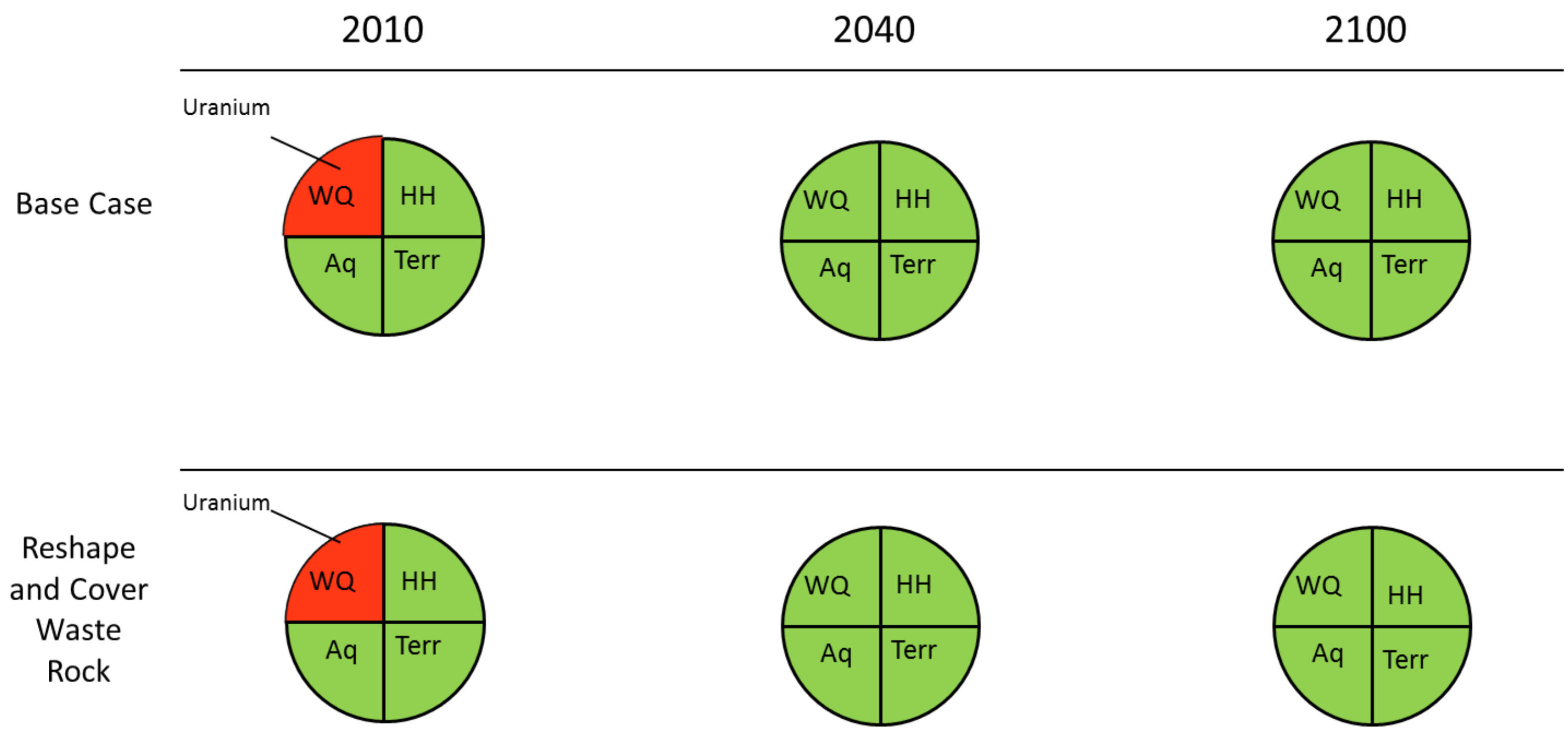


Figure 2.4-9 Summary of Outcomes in Ace Lake (Reshape and Cover Bolger/Verna Waste Rock)



2.4.3.3 Cover Verna Lake Sediments

This activity involves applying a sand cover to sediments in Verna Lake to act as a barrier to reduce the flux of contaminants from the sediment and also reduce contact of biota with contaminants present in the sediment porewater and solids. Covering of sediments would be achieved by pumping and placing sand slurry onto the sediment surface by barge. It is assumed that borrow materials for this activity would be locally sourced from previously identified areas (SENES & SRK 2012).

Potential change to environmental conditions based on covering sediments in Verna Lake was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of covering sediments in Verna Lake are:

- Cover material assumed to be a typical sandy fill (porosity of 0.4 and tortuosity of 3).
- 10 cm of cover material placed, mixes with the top 5 cm of pre-existing sediments
- Able to effectively cover 95% of the Verna lakebed

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 17% from 2.9×10^4 kBq/yr to 2.4×10^4 kBq/yr, a reduction in uranium load of 15% from 65 kg/yr to 55 kg/yr and a reduction in selenium load of 14% from 0.041 kg/yr to 0.036 kg/yr to the downstream environment.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.4-10 and 2.4-11. Some reductions in uranium and radium-226 are seen in the immediate area (Verna Lake), while very little benefit is seen in the downstream environment (Ace Lake). A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.4-12 and 2.4-13 for Verna Lake and Ace Lake as compared to the base case, with no remediation. As can be seen, application of this sediment cover does not change the predicted exceedances in Ace Lake but is expected to reduce risk to scaup in Verna Lake. Risks to assessed receptors in the Ace Lake area are predicted to be below the SI benchmarks for the entire modeled period both with and without the application of this sediment cover.

Costs of applying this sand cover to sediments in Verna Lake are estimated based on similar activities presented in SENES & SRK (2012) to be approximately $6.0 million CAD.

Figure 2.4-10 Verna Lake Water Quality Predictions (Cover Verna Lake Sediments)

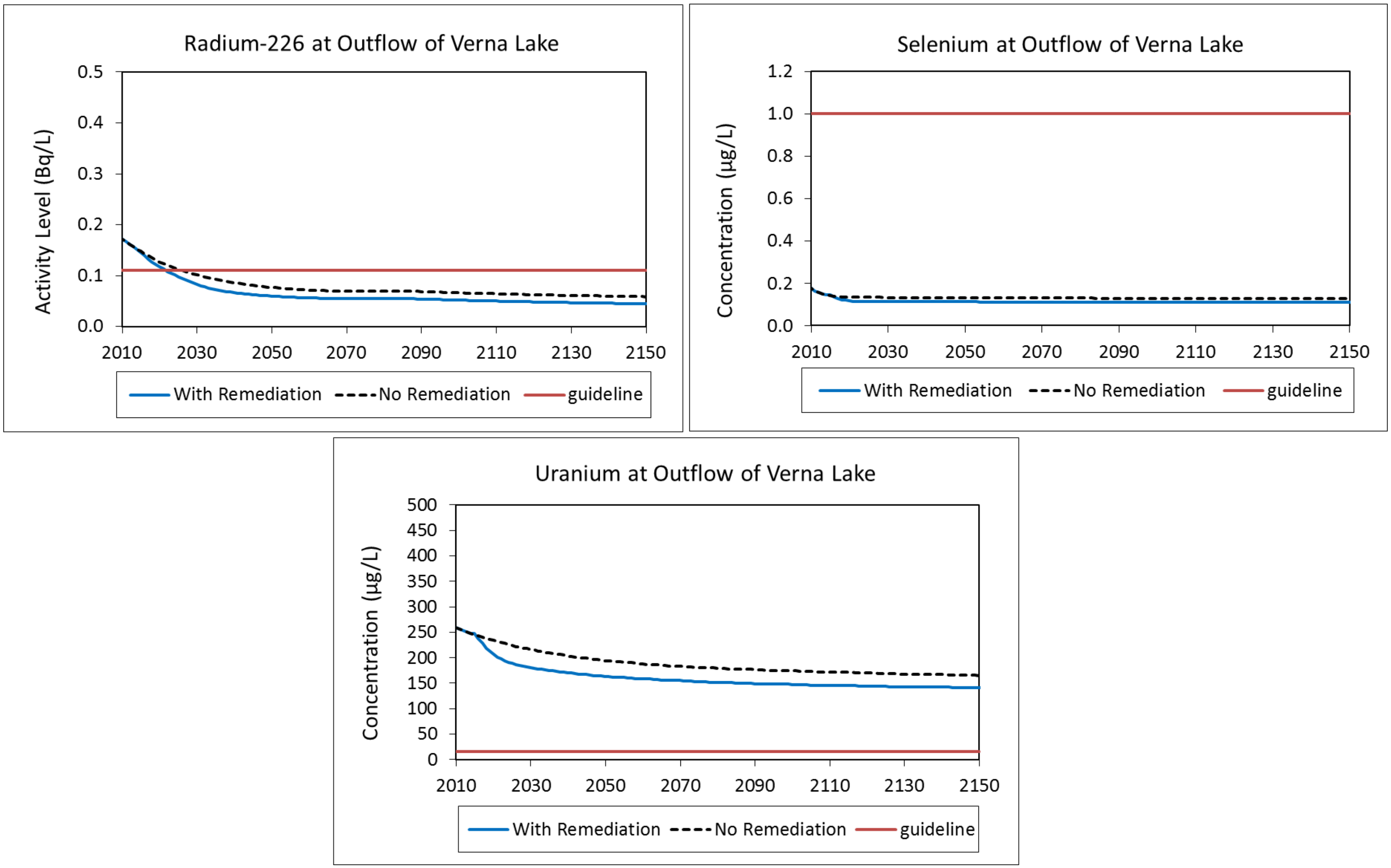


Figure 2.4-11 Ace Lake Water Quality Predictions (Cover Verna Lake Sediments)

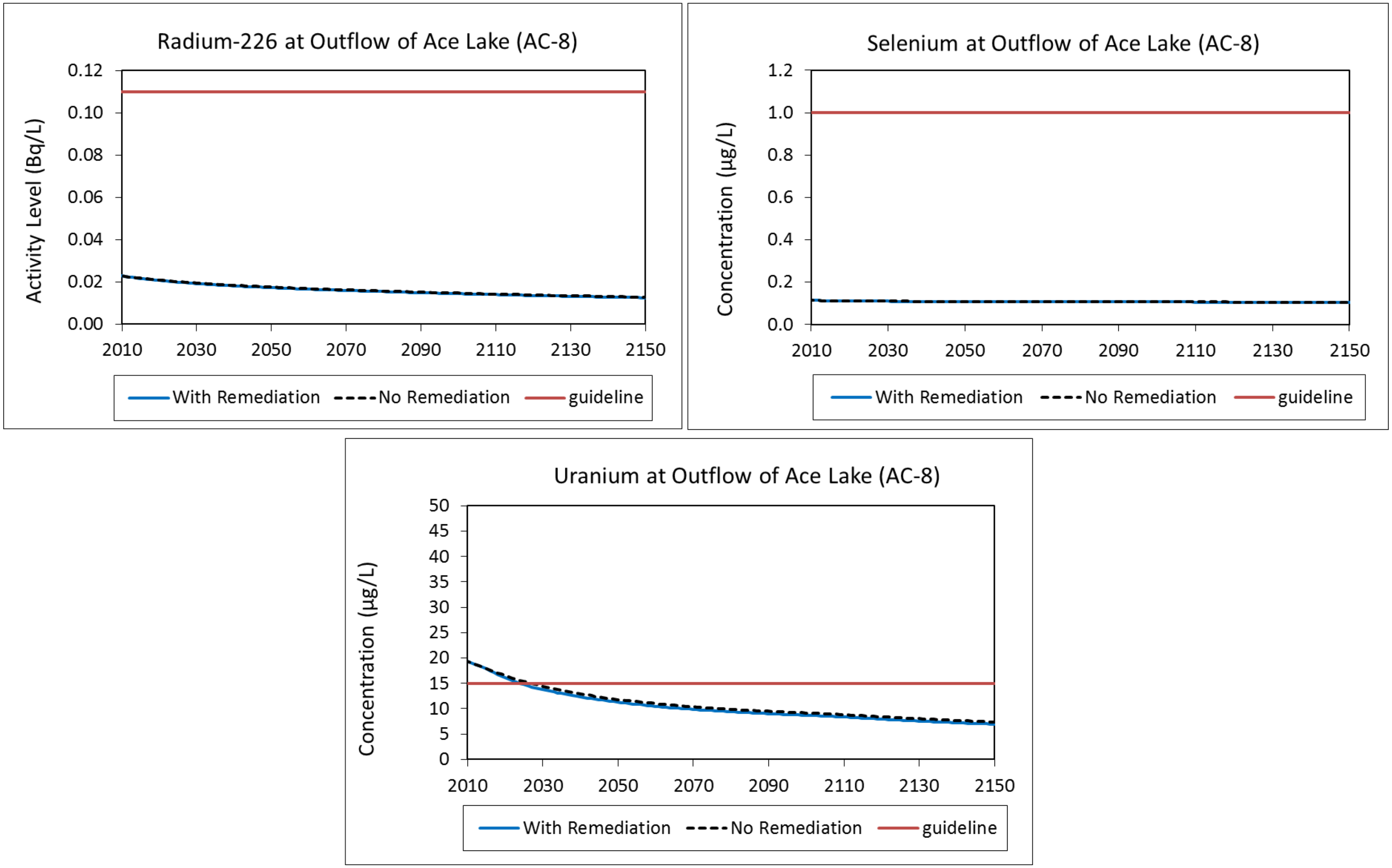


Figure 2.4-12 Summary of Outcomes in Verna Lake (Cover Verna Lake Sediments)

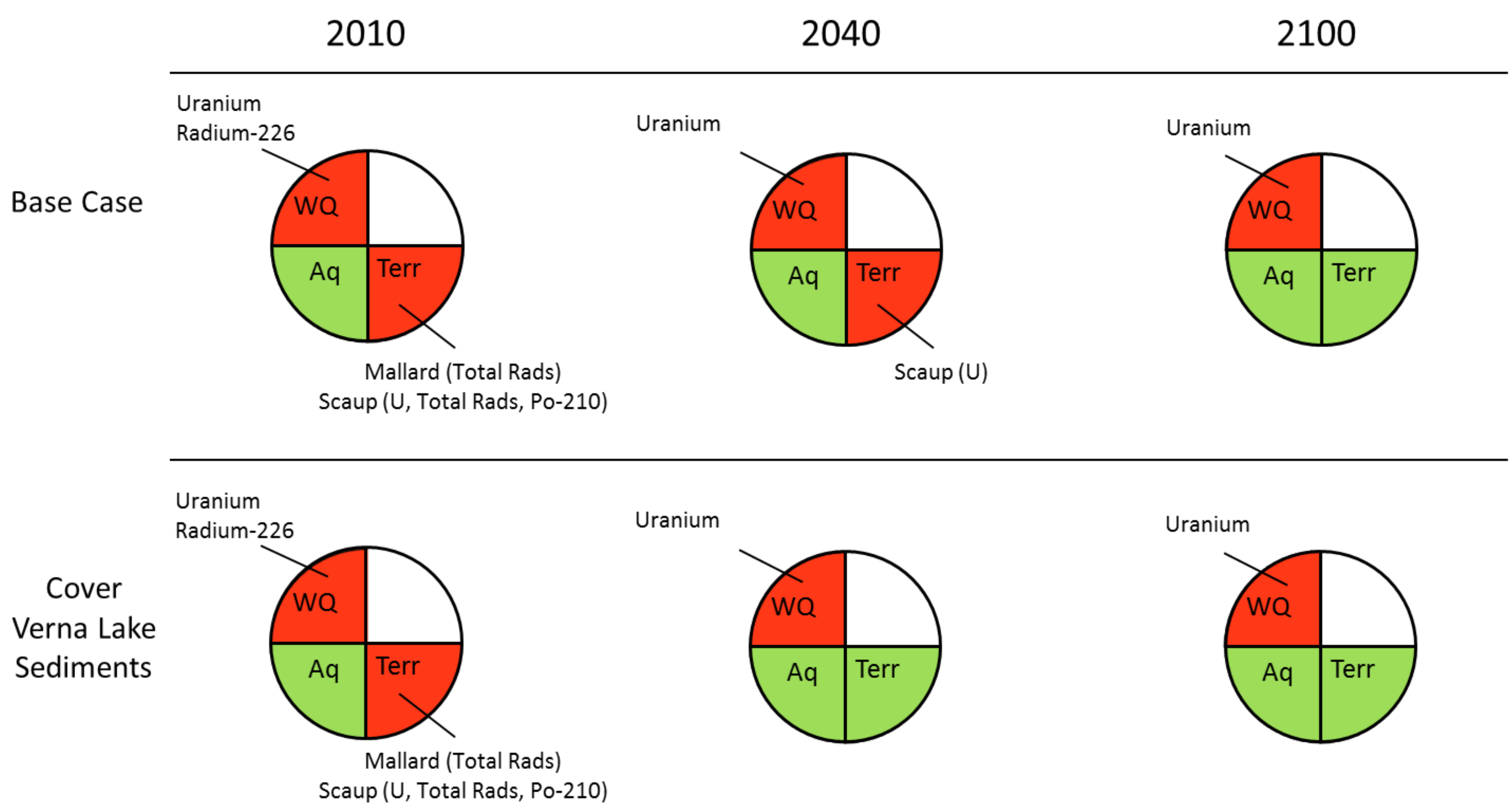
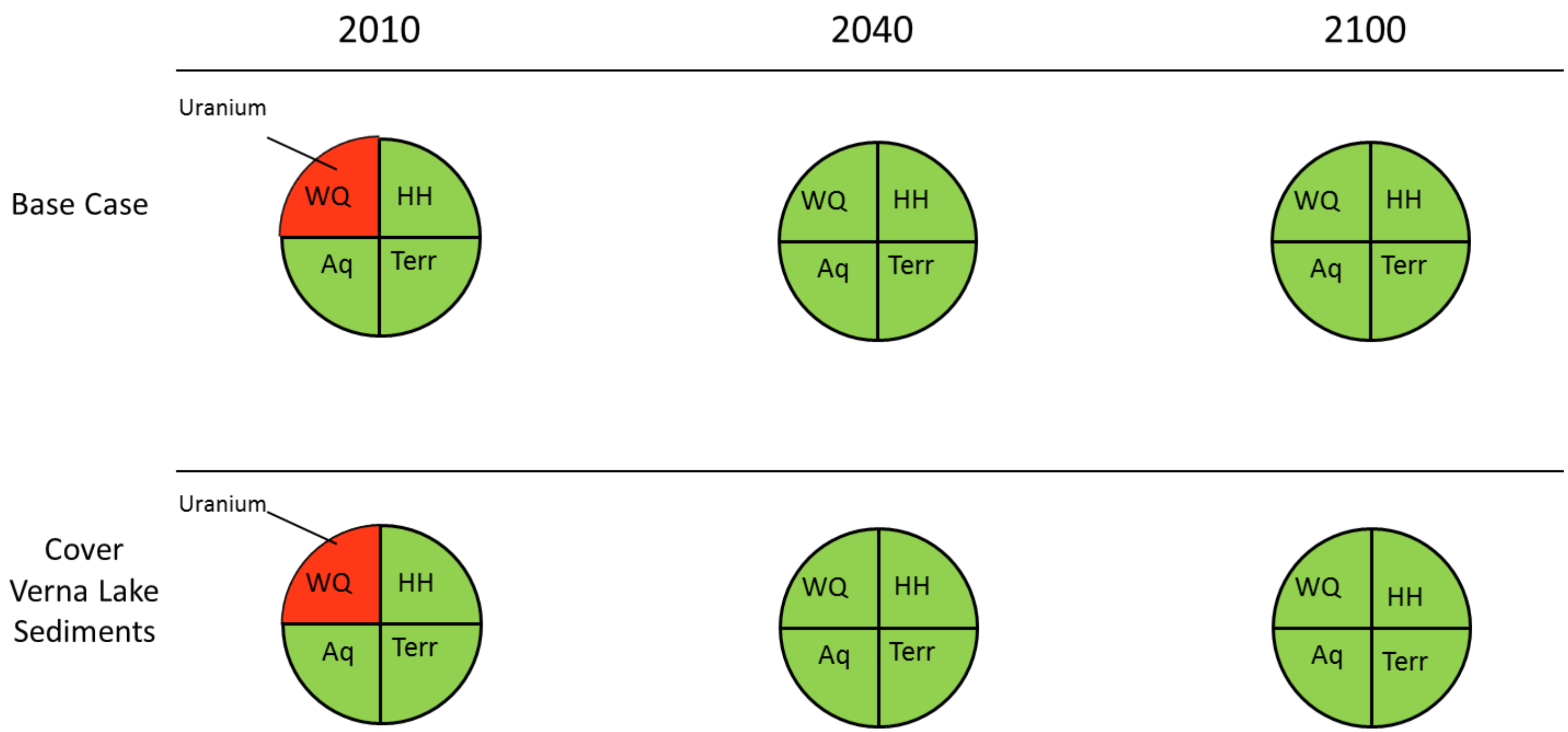


Figure 2.4-13 Summary of Outcomes in Ace Lake (Cover Verna Lake Sediments)



2.4.3.4 Water Treatment at the Outlet of Verna Lake

This activity involves installation of a water treatment system and associated dam structure at the outlet of Verna Lake. The Beaverlodge Costing Report (SENES & SRK 2012) looked at long-term removal of uranium only. Details of this system are provided in SENES & SRK (2012). The investigated system to handle uranium removal is an on-site ion exchange plant with an operating capacity of 310,000 m^3/yr over an operating period of 200 days/yr. The used resin generated by the operation of this system would be transported to one of Cameco's mills for uranium recovery on an annual basis. Disposal of the used resin may require additional regulatory approval.

Potential effects of treating for uranium removal at the outlet of Verna Lake were assessed using the Beaverlodge QSM (SENES 2012a) assuming the installation of the treatment facilities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- Operating capacity of water treatment system is 310,000 m^3/yr, additional water discharges downstream untreated
- System able to achieve concentrations of:
    - Uranium: 10 µg/L

Over the first 50 years of implementation, these assumptions result in a predicted reduction in uranium load of 95% from 65 kg/yr to 4 kg/yr to the downstream environment. However, after 50 years of operation, either an additional investment will be required to maintain/replace the treatment facility or the load to the downstream environment will be the same as if water treatment had never occurred.

Predicted water quality in the downstream environment (Ace Lake) over the 2010-2150 period is shown in Figure 2.4-14. Water treatment at the outlet of Verna Lake will not impact water quality within Verna Lake and therefore is not shown. There is some predicted improvement in uranium levels in the water column of Ace Lake as a result of this remedial measure, however, it should be noted that predicted uranium levels in Ace Lake without remediation are only in exceedance of the applicable guideline in the first few decades. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figure 2.4-15 for Ace Lake as compared to the base case, with no remediation. As can be seen, implementation of this water treatment system does not significantly change the predicted water quality in Ace Lake. Risks to assessed receptors the Ace Lake area are predicted to be below the SI benchmarks for the entire modeled period both with and without this activity.

It should also be noted that this remediation activity involves perpetual maintenance of the water treatment system and associated dam structure at the outlet of Verna Lake.

Costs of installation as well as long-term operation and maintenance of the water treatment plant at the outlet of Verna Lake were estimated by SENES & SRK (2012) to be approximately $36.8 million CAD. These costs include the NPV of an annual operating and maintenance cost of $1.1 million CAD.

Figure 2.4-14 Ace Lake Water Quality Predictions (Water Treatment at Verna Lake Outlet)

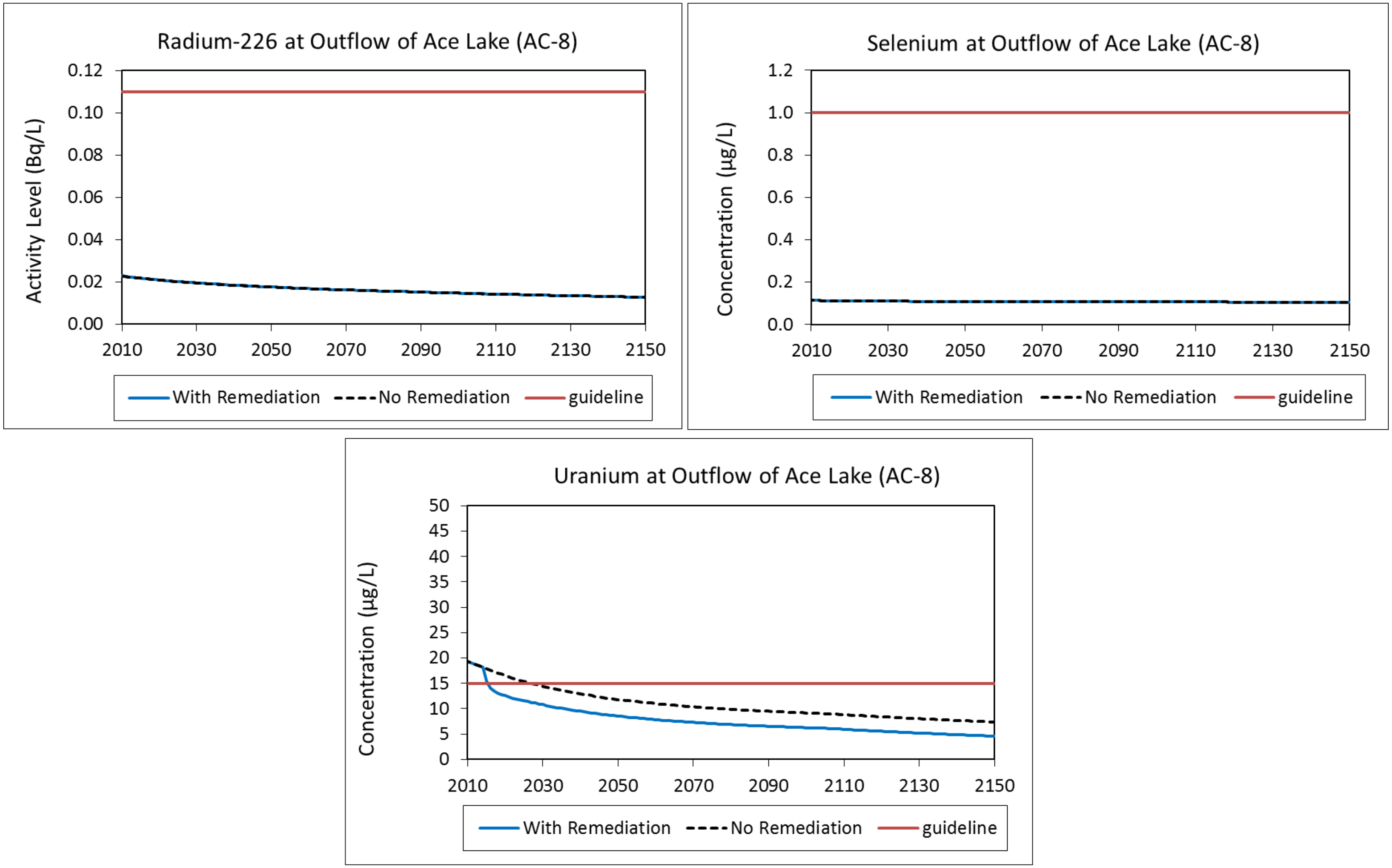
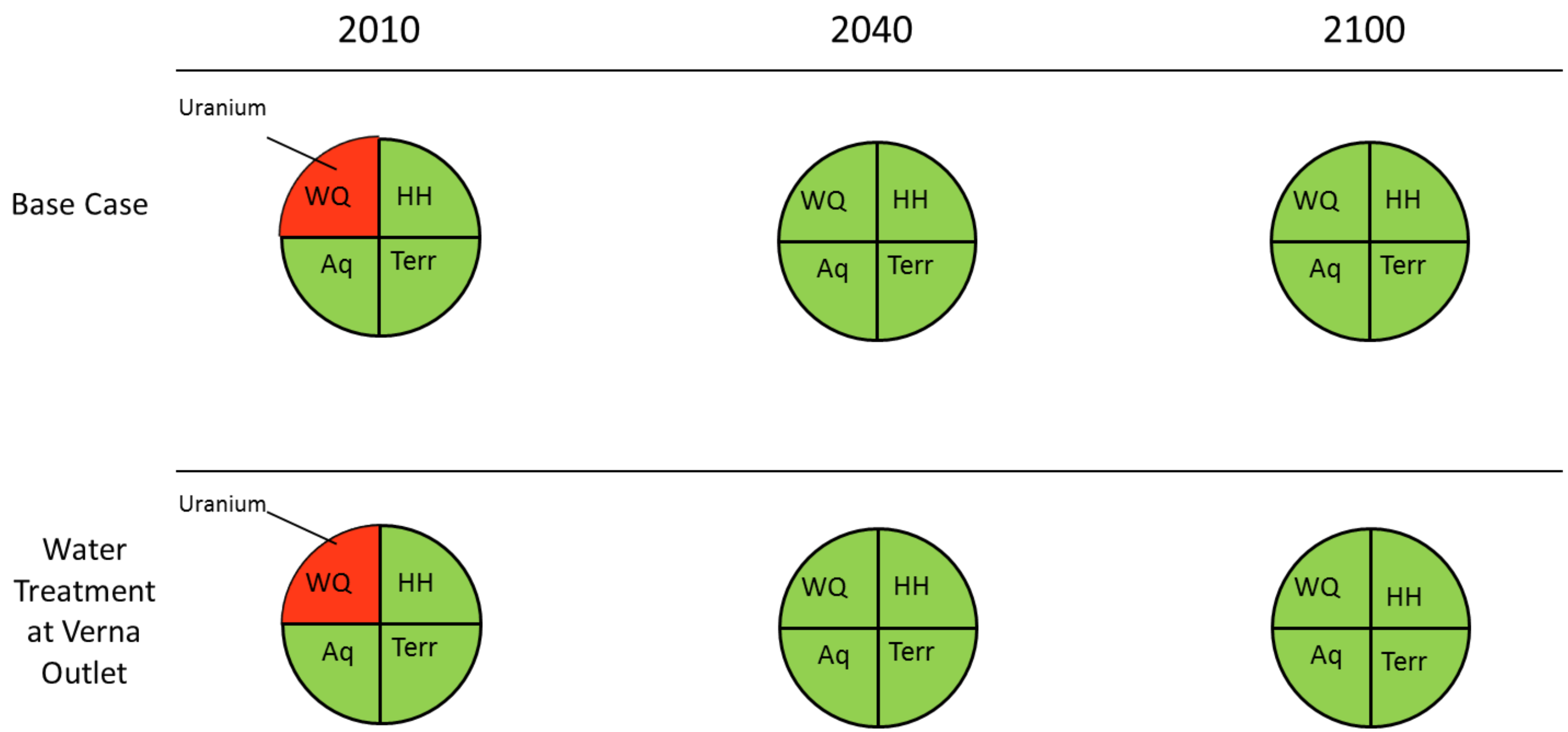


Figure 2.4-15 Summary of Outcomes in Ace Lake (Water Treatment at Verna Lake Outlet)



2.4.3.5 Replacement of Caps on Vertical Openings

This activity involves replacing the original concrete caps on all vertical mine openings in the Bolger/Verna area with an engineered cap, which may include concrete or stainless steel. The decommissioning documentation (MacLaren Plansearch 1987) identifies four openings in the Bolger/Verna area; one of these openings is indicated in Figure 2.4-1. It is possible that exploration work may be required to locate the remaining vertical mine openings.

It is not anticipated that this activity would result in any change to the immediate or downstream environments; however, it is included for discussion as it is considered to be good engineering practice and would improve the long-term safety of the site for humans and wildlife frequenting the area. It is assumed that these engineered caps would require an assessment of condition after a period of between 75 and 100 years and more frequently following. For the calculation of future monitoring and maintenance costs it is assumed that the caps will require replacement every 100 years although this is overly conservative.

The cost of replacing these vertical mine opening caps was estimated to be approximately $70,000 (SENES & SRK 2012) for each cap based on previous experience as well as an additional cost of approximately $70,000 for mobilization, de-mobilization, site preparation and site clean-up.

2.4.3.6 Plug Identified Boreholes

Flowing boreholes have not been identified on this property. This activity involves applying grout to all identified non-flowing boreholes in the Bolger/Verna Mine area. This activity is considered to be good engineering practice as it reduces the risk that these openings might serve as conduits for mine water in the future.

Plugging non-flowing boreholes will not affect the immediate or downstream environments.

Estimated costs of plugging identified non-flowing boreholes are approximately $10,000 CAD. If flowing boreholes are identified in the future, they will be plugged at an estimated cost of $75,000 each.

2.4.4 Bolger/Verna Selection of Remedial Activities

In addition to predicted changes to the environment as assessed by the Beaverlodge QSM (SENES 2012a) and estimated costs of assessed activities (SENES & SRK 2012), opinions expressed during the Beaverlodge Remedial Option Workshop (ASKI, SENES & SRK 2012) were used as additional information to inform the remedial activity evaluation process. Outcomes from these three sources are discussed below. In addition, the costs and benefits for each of the remedial measures considered for the Bolger/Verna area are summarized in Table 2.4-2. For each remedial activity expected change to exceedances, predicted reduction in loads, estimated costs as well as calculated cost per unit reduction are presented.

Table 2.4-2 Summary of Predicted Effects of Remedial Activities, Bolger/Verna Area

Remedial Measure	Change to Water Quality or Human/Eco Risk?[a,b]	Reduction in Load to Downstream Environment[c]			Estimated Costs (CAD)	Cost per Unit Reduction[c]			Comments
		Ra-226 (MBq/yr)	Se (kg/yr)	U (kg/yr)		Ra-226 (CAD/kBq/yr)	Se (CAD/g/yr)	U (CAD/g/yr)	
Divert Zora Lake outflow around waste rock	reduced risk to scaup in Verna Lake	6.6 (22%)	-	24 (37%)	$1,700,000 to $1,800,000	270	-	80	-predicted effect on contaminant loads downstream of Verna Lake minimal -can be implemented without synthetic liners or damming which would require long term maintenance -good engineering practice
Reshape and cover Bolger/Verna waste rock piles	no change to exceedances	0.5 (2%)	-	1.9 (3%)	$2,900,000 to $6,200,000	11,920	-	3,260	-predicted effect on contaminant loads downstream of Verna Lake minimal
Place Cover on Verna Lake sediments	no change to exceedances	4.9 (17%)	0.006 (15%)	9.4 (14%)	$6,000,000	1,220	1,000,000	640	-predicted effect on contaminant loads downstream of Verna Lake minimal
Treat water at the outlet of Verna Lake	no change to exceedances	-	-	61.4 (95%)	$36,800,000	-	-	600	-cost of water treatment at the outlet of Verna Lake unjustifiably high -additional regulatory licensing requirement -requires ongoing operation and maintenance of treatment facility
Replace caps on vertical mine openings	no change to exceedances	-	-	-	$350,000	-	-	-	-good engineering practice -reduces future hazard to those using the site -no predicted effect on contaminant loads
Plug identified non-flowing boreholes	no change to exceedances	-	-	-	$10,000	-	-	-	-no effect on contaminant loads -good engineering practice

Notes:

[a] for the base case scenario (no remediation), there is no predicted risk to any assessed ecological receptors in Ace Lake throughout the modeled period.
[b] human receptors assessed at Ace Lake but not Verna Lake
[c] load reductions estimated over the first 50 years after implementation

Diverting Zora Lake outflow to avoid contact with the waste rock pile, while predicted to have only a minimal beneficial effect on the downstream environment, is considered to be good engineering practice. This activity is seen to provide some benefit to water quality in Verna Lake although the SSWQO will still not be achieved for uranium, for the foreseeable future. The benefit of implementing this option is largely limited to Verna Lake as the benefit is greatly reduced downstream in Ace Lake. In addition, predicted risk to scaup using the Verna Lake area is seen to be reduced as a result of implementing this stream diversion. This stream diversion was discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). Stakeholders were generally in favor of this diversion as it is relatively low cost with some benefit to water quality and it restores watershed continuity in the Bolger/Verna area. Of the three discussed diversion options, the preferred design is the plan which provides for excavation of waste rock to form an unlined channel from Zora Lake through to Verna Lake. This is preferred as it is the only diversion scheme which would not involve long term maintenance of a dam or HDPE liner. This remedial activity has the most favorable estimated cost per unit reduction of all activities examined for the Bolger/Verna Mine site based on the predicted load reductions and estimated costs.

Reshaping and covering of the Bolger/Verna waste rock piles is seen to have no significant benefit to the immediate and downstream environment. This activity was discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). During discussions it became clear that many stakeholders felt that waste rock cover activities throughout the Beaverlodge study area are not justified due to the high cost and minimal benefit achieved.

Application of a sand cover on the sediments of Verna Lake are predicted to have some minimal benefit in the immediate area, however, this benefit is not seen in the downstream environment. This remedial activity was discussed during the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). During this workshop many stakeholders expressed their opinion that disruptive works such as the application of a sand cover within Verna Lake is undesirable due to the close proximity to the bible camp located near where the outlet from Verna Lake enters Ace Lake. Concerns were also raised that the costs of applying this cover are very high given the minor benefit achieved. This concern is justified by the relatively high cost per unit reduction seen for this remedial activity.

Water treatment at the outlet of Verna Lake is predicted to improve uranium levels in Ace Lake, however, this predicted risks to receptors in the Ace Lake area were already low prior to any remedial activities. Due to time constraints, this measure was not discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). The estimated cost of water treatment at the outlet of Verna Lake is considered by Cameco to be unjustifiably high given the minor benefit achieved downstream.

Replacing the caps on the vertical mine openings in the area is not expected to influence water quality in the area, however, it is considered to be good engineering practice as it reduces the risk of cap failure in the future. Similarly, plugging non-flowing boreholes in the area will not benefit the environment but is considered to be a good engineering practice. These activities will also prepare the site for eventual transfer into the provincial IC Program.

Based on the evaluation presented above, the course of action developed by Cameco for the Bolger/Verna site is to divert Zora Lake outflow to reduce contact with waste rock; locate, assess and replace the caps on all vertical mine openings with acceptable engineered structures; plug all identified non-flowing boreholes; and continue monitoring the area to ensure that recovery is progressing as expected. The other considered activities are not justifiable based on the lack of expected benefit to the local and downstream environment in relation to the cost of implementing the activities.

2.5 LOWER ACE CREEK AREA

The Lower Ace Creek area is located within the Ace Creek Watershed downstream of Ace Lake. Ace Lake receives water from the Hab, Dubyna and Bolger/Verna Mine sites. Water from the Lower Ace Creek area (shown in Figure 2.5-1) flows to Ace Bay of Beaverlodge Lake.

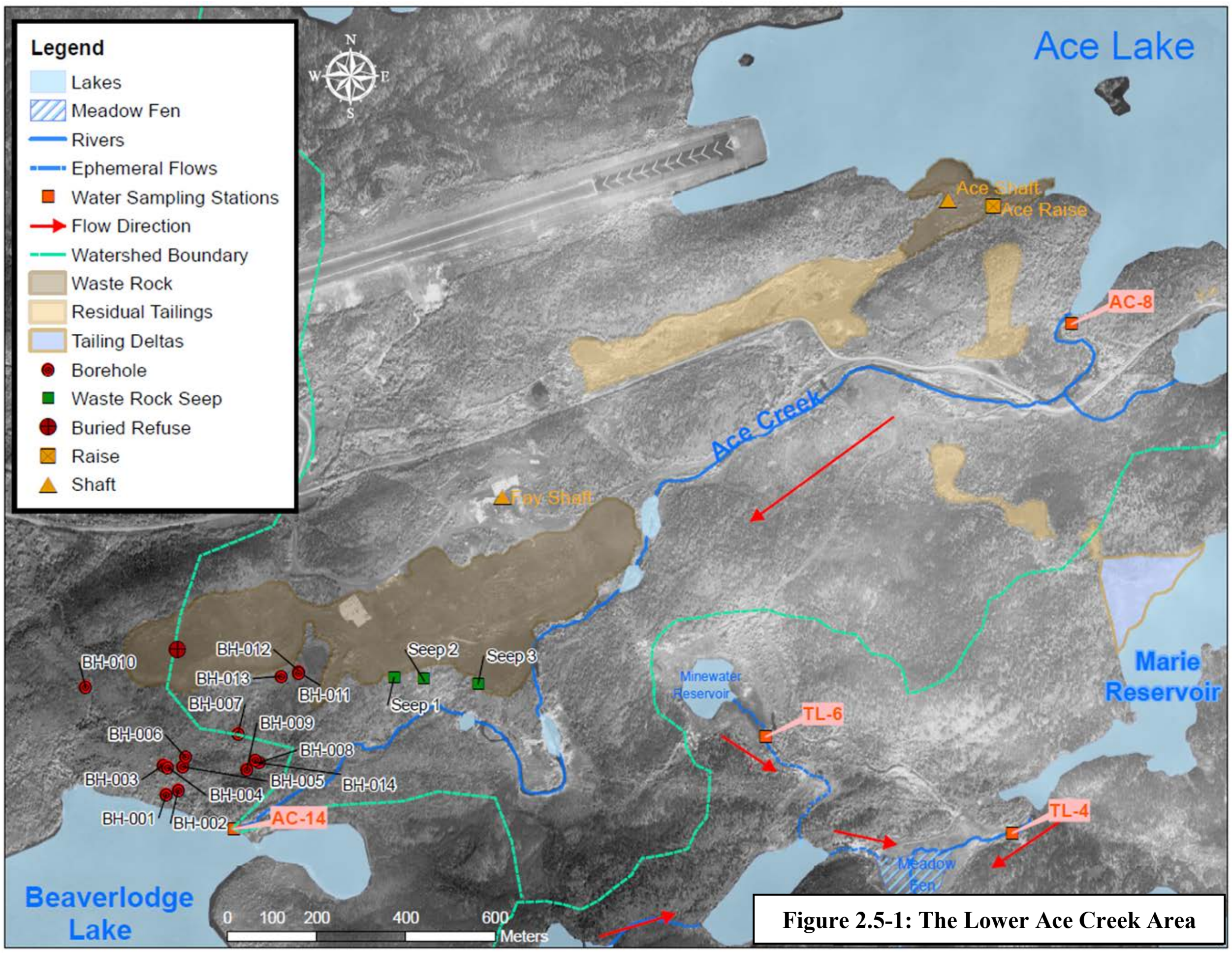


Figure 2.5-1: The Lower Ace Creek Area

2.5.1 Lower Ace Creek Area Features

The main features of the Beaverlodge mine/mill complex, located in Lower Ace Creek, are depicted in Figure 2.5-1. The features include: the site of the former mill complex which was partially demolished at closure and covered with waste rock; a small waste rock pile, from the development of Ace shaft, on the shoreline of Ace Lake in the vicinity of the Ace shaft and raise; tailings deposited on surface in the vicinity of the former Dorrclone plant (not shown) also near the Ace shaft and raise; the Fay shaft located near the former mill site; and, the Lower Ace Creek (Fay) waste rock pile, which is the largest of the Beaverlodge waste rock piles and is located along the north shore of Ace Creek between Ace Lake and Beaverlodge Lake.

Reclamation activities undertaken between 1982 to 1985 included: salvage of reusable equipment and disposal of contaminated material underground; demolition of the Fay service building and headframe, which were moved to the mill site for burial; partial demolition of the mill to permit filling of the basement with waste rock; capping of surface openings (mine shafts and vent raises) with reinforced concrete; and general clean-up of the mine site. Exposed tailings in the Ace Creek floodplain were removed and disposed underground. All accessible exposed tailings (40%) in the other areas were covered with 600 mm of waste rock or sand and gravel. Inaccessible tailings (60%), those that were already naturally vegetated or located within heavily wooded areas, were left undisturbed.

Water quality monitoring in Lower Ace Creek has been undertaken on a routine basis at two locations; at the outlet of Ace Lake (AC-8) and at the outlet of Lower Ace Creek to Ace Bay of Beaverlodge Lake (AC-14). In addition, samples have been collected from seeps and flowing boreholes, the location of which are indicated in Figure 2.5-1. Ongoing reclamation activities have included plugging of flowing boreholes as they are identified during annual site surveys. Field surveys along the length Ace Creek between stations AC-8 and AC-14 have shown an increase in contaminants of concern adjacent to the former mill site in particular (Cameco 2009 and Golder 2010).

2.5.2 Lower Ace Creek Assessment of Potential Risks

In order to select remedial measures, the potential risks that various features within the Lower Ace Creek area may pose to the environment and members of the public accessing the site were assessed. Site aspects examined included mining geotechnical; surface water; contaminated substrate; air, radon and gamma; terrestrial and aquatic vegetation; and risk communication. When determining a relative risk rating for each site element likelihood of the event occurring as well as the consequence of that event were considered. The resulting relative risk estimates for the Lower Ace Creek area are shown in Table 2.5-1

Table 2.5-1 Summary of Estimated Risks, Lower Ace Creek Area

Aspect	Specific Location	Site Element	Current Risk Registry		Risk Endpoints		References
			Event	Effect	Environment Risk	Public Health and Safety Risk	
Mining Geotechnical	**Ace**	**Ace Crown Pillar**	Pillar failure (collapse)	Formation of sinkholes creating a falling hazard for wildlife and human	**L**	**ML**	Screening Level Risk Assessment, Cameco 2010b.
	Faye	**54 Zone**	Pillar failure (collapse)	Formation of sinkholes creating a falling hazard for wildlife and human	**L**	**ML**	Screening Level Risk Assessment, Cameco 2010b.
	General	**Waste Rock Pile**	Slope instability and failure	Falling hazard for wildlife and human	**L**	**L**	Waste Rock Stability Assessments: Former Eldorado Beaverlodge Sites, SRK 2010
			Slumping of waste rock pile	Formation of sinkholes creating a falling hazard for wildlife and human	**L**	**ML**	Screening Level Risk Assessment, Cameco 2010b.
		Demolition Material	Erosion causing exposure of material	Safety concern, e.g. falling hazards or collision	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
			Slumping of demolition material	Formation of sinkholes creating a falling hazard for wildlife and human	**L**	**ML**	Screening Level Risk Assessment, Cameco 2010b.
		Sealed Openings to Surface	Cap fails (19 vertical openings to surface)	Formation of opening (vertical hole) to underground workings creating a falling hazard for wildlife and human	**M**	**M**	Departure With Dignity: Decommissioning of the Beaverlodge Mine/Mill. MacLaren Plansearch 1987.
			Adits (3 horizontal openings to surface)	Open access to workings	**L**	**L**	Departure With Dignity: Decommissioning of the Beaverlodge Mine/Mill. MacLaren Plansearch 1987.
Surface Water (including Surface Tailings, Seeps and Flowing Drillholes)	**Surface Tailings**	**Ace Stope Area**	Tailings spills from any of the site elements	Impact Ace Creek water quality	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Ace Creek Characterization Report. Cameco 2009. Departure With Dignity: Decommissioning of the Beaverlodge Mine/Mill. MacLaren Plansearch 1987.
		Catchment I			**ML**	**L**	
		Catchment II & III			**ML**	**L**	
		Tailings Lines			**ML**	**L**	
		Minewater Channel			**ML**	**L**	
	General	**Waste Rock Pile**	Precipitation infiltration and surface runoff from the waste rock into Ace Creek	Impact on Ace Creek water quality	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Conceptual Site Model. Cameco 2010a. Results of Investigations into the Remediation of Flowing Boreholes. Golder 2010. Ace Creek Characterization Report. Cameco 2009.
			Flow from mill area seeps and covered boreholes to surface water		**M**	**L**	
		Demolition Material	Erosion of demolition material and discharge to Ace Creek	Impact Ace Creek/ Beaverlodge Lake	**ML**	**L**	Screening Level Risk Assessment, Cameco 2010b.
		Identified Flowing Drill Holes	Seepage to surface water	Impact on Beaverlodge Lake water quality	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009. Results of Investigations into the Remediation of Flowing Boreholes. Golder 2010.
	Lower Ace Creek Area	**Lower Ace Creek Water**	Discharge to downstream waters	Impact on Beaverlodge Lake water quality	**L**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a.

Table 2.5-1 Summary of Estimated Risks, Lower Ace Creek Area (Cont`d)

Aspect	Specific Location	Site Element	Current Risk Registry		Risk Endpoints		References
			Event	Effect	Environment Risk	Public Health and Safety Risk	
Contaminated Substrate	**Ace Creek**	**Substrate**	Accumulation of contaminants in sediment	Impact on Lower Ace Creek water quality	**L**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Aquatic Macrophyte Sampling Program. CanNorth 2011a.
Air, Radon and Gamma	**General**	**Waste Rock**	Dusting of waste rock and release of airborne contaminants	Inhalation exposure for wildlife and human	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
			Radon release from exposed rock	Prolonged radon exposure for wildlife and human	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
			Gamma exposure from waste rock	Prolonged gamma exposure for wildlife and human	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.
		Tailings Spills	Gamma exposure from tailings spills	Prolonged gamma exposure for wildlife and human	**L**	**ML**	Screening Level Risk Assessment, Cameco 2010b.
Terrestrial and Aquatic Vegetation	**General**	**Terrestrial Vegetation**	Release of COPC to air	Potential uptake of contaminants in vegetation and impact to VECs	**L**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Country Foods Survey. SENES 2012b. Draft.
		Aquatic Vegetation	Leaching of COPC to water	Potential uptake of contaminants in vegetation and impact to VECs	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Aquatic Macrophyte Sampling Program. CanNorth 2011a. Country Foods Survey. SENES 2012b. Draft.
Risk Communication	**General**	**-**	Public notification of any site risk	If not done in a timely manner may cause public safety risk	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.

As can be seen within Table 2.5-1, potential events which were estimated to pose the greatest risk to the environment and public accessing the site include failure of caps on vertical mine openings and flow from mill area seeps and covered boreholes to surface water; remedial measures examined within the following section are focused on these features and potential events. It should be noted that none of the risks from this area are ranked ‘high’.

2.5.3 Lower Ace Creek Assessment of Remedial Activities

Potential remedial measures considered based on identified risks and/or to meet the standard of good engineering practice within the Lower Ace Creek Mine site include:

- Reshape and cover waste rock pile
- Cover exposed tailings
- Plug identified flowing boreholes
- Treat mill seep for uranium and selenium removal
- Excavate waste rock pile and plug additional boreholes and other conduits for mine water flow
- Replace caps on vertical openings
- Plug identified non-flowing boreholes

Each of these activities will be discussed in the following sections.

2.5.3.1 Reshape and Cover Waste Rock Pile

This remedial measure involves re-contouring the Fay waste rock pile to better fit the surrounding landscape and then covering the pile with either a sand cover or a synthetic liner (such as HDPE). It should be noted that placement of a cover on the Fay waste rock pile is predicted to only reduce the flow of precipitation down through the pile and is not assumed to affect loads due to flow from the former mill site or the underground workings.

Potential change to environmental conditions based on reshaping and covering the waste rock pile in the Lower Ace Creek area was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- As discussed in SENES & SRK (2012), with proper installation of a geo-synthetic liner such as the one discussed in this section, the percolation rates in the waste rock may be reduced to ~5% from 39%. The reduction in percolation through the waste rock pile is predicted to be much less with a sand cover, however, this option was assessed assuming the best case scenario.

- The annual precipitation rate for the region and base case percolation rate for the waste rock pile are discussed in SENES (2012) and were assumed to be 273 mm/a and 39%, respectively.

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 0.6% and a reduction in uranium load of 2% to the downstream environment.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.5-2 and 2.5-3. Almost no change to radium-226, selenium or uranium levels in Lower Ace Creek or Ace Bay of Beaverlodge Lake is seen as a result of reshaping and covering the waste rock pile. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.5-4 and 2.5-5 for Lower Ace Creek and Ace Bay of Beaverlodge Lake as compared to the base case, with no remediation. As can be seen, implementation of this remedial activity does not change the exceedances predicted in either Lower Ace Creek or Ace Bay of Beaverlodge Lake. Although uranium is predicted to be in exceedance of the applicable guideline in Lower Ace Creek over the first few decades, predicted risk to the evaluated receptors are not anticipated to exceed the SI benchmarks. The results presented are for application of a geo-synthetic liner and if a sand cover is selected instead, the predicted benefit of this activity would be even less.

Costs of covering the Fay waste rock pile were estimated by SENES & SRK (2012) to be between approximately $13 and $28 million CAD for sand and geo-synthetic covers, respectively. These estimated costs include the net present value (NPV) of a $10,000 CAD per year maintenance expense.

Figure 2.5-2 Lower Ace Creek Water Quality Predictions (Reshape and Cover Fay Waste Rock Pile)

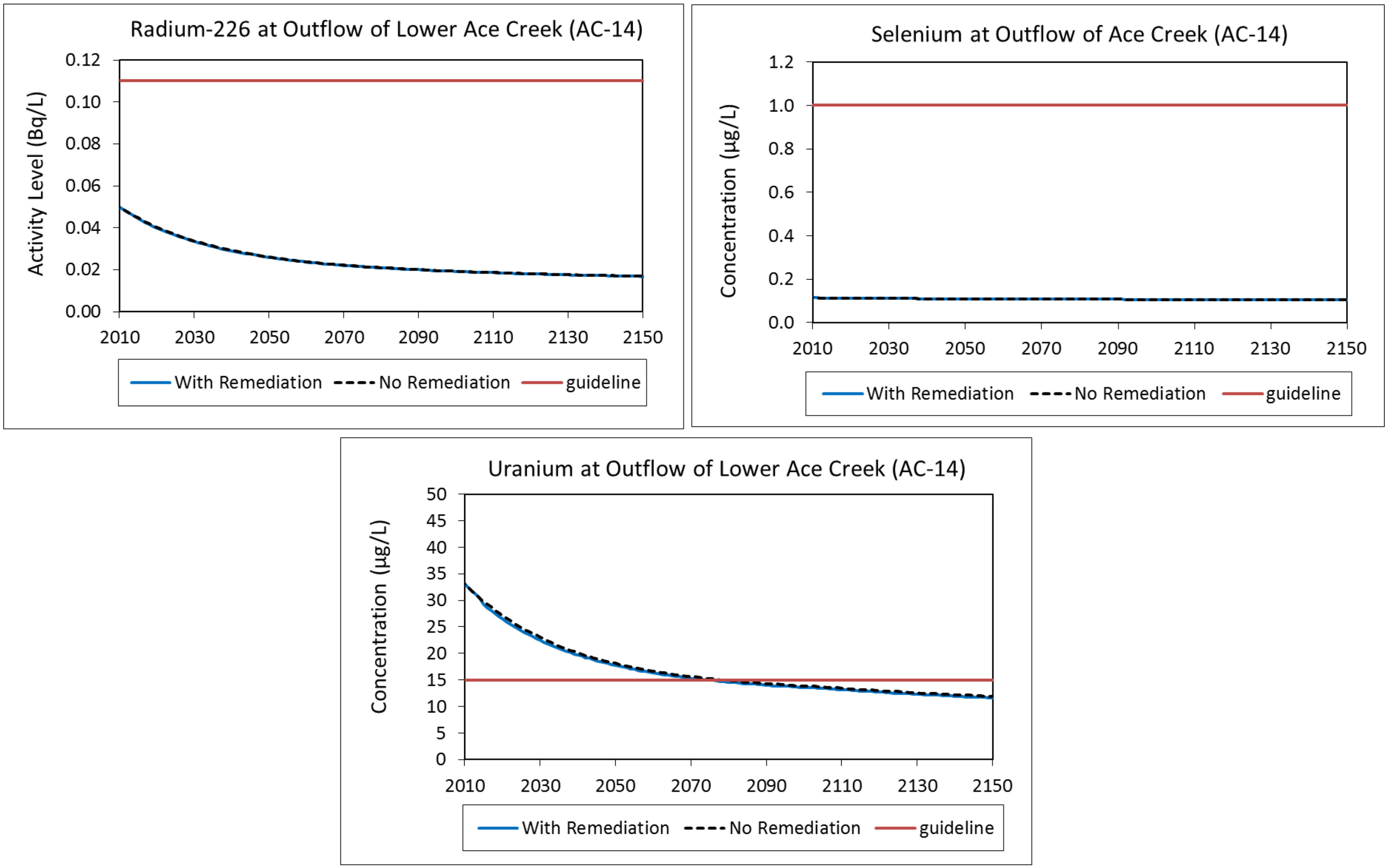


Figure 2.5-3 Ace Bay, Beaverlodge Lake Water Quality Predictions (Reshape and Cover Fay Waste Rock Pile)

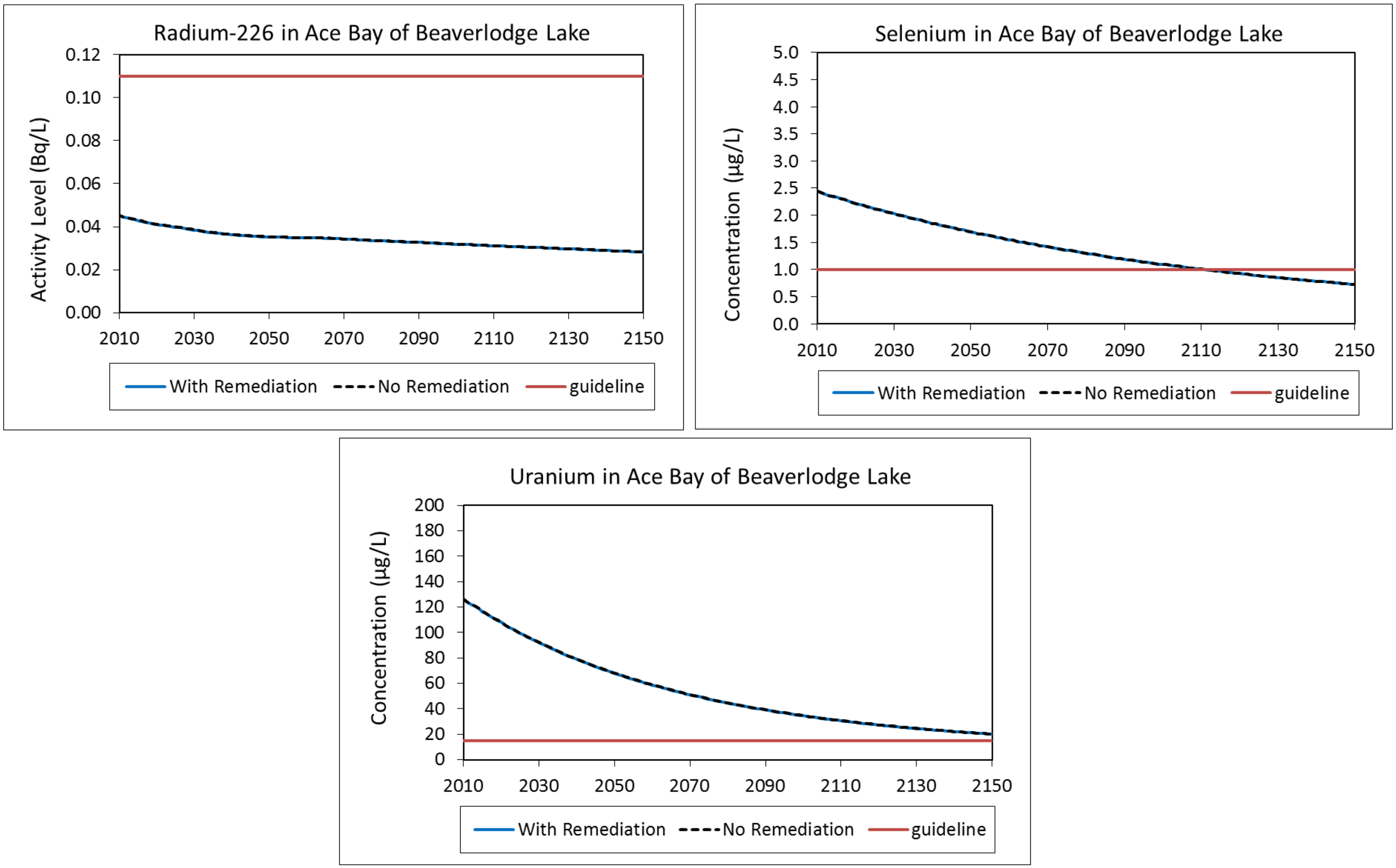


Figure 2.5-4 Summary of Outcomes in Lower Ace Creek (Reshape and Cover Fay Waste Rock Pile)

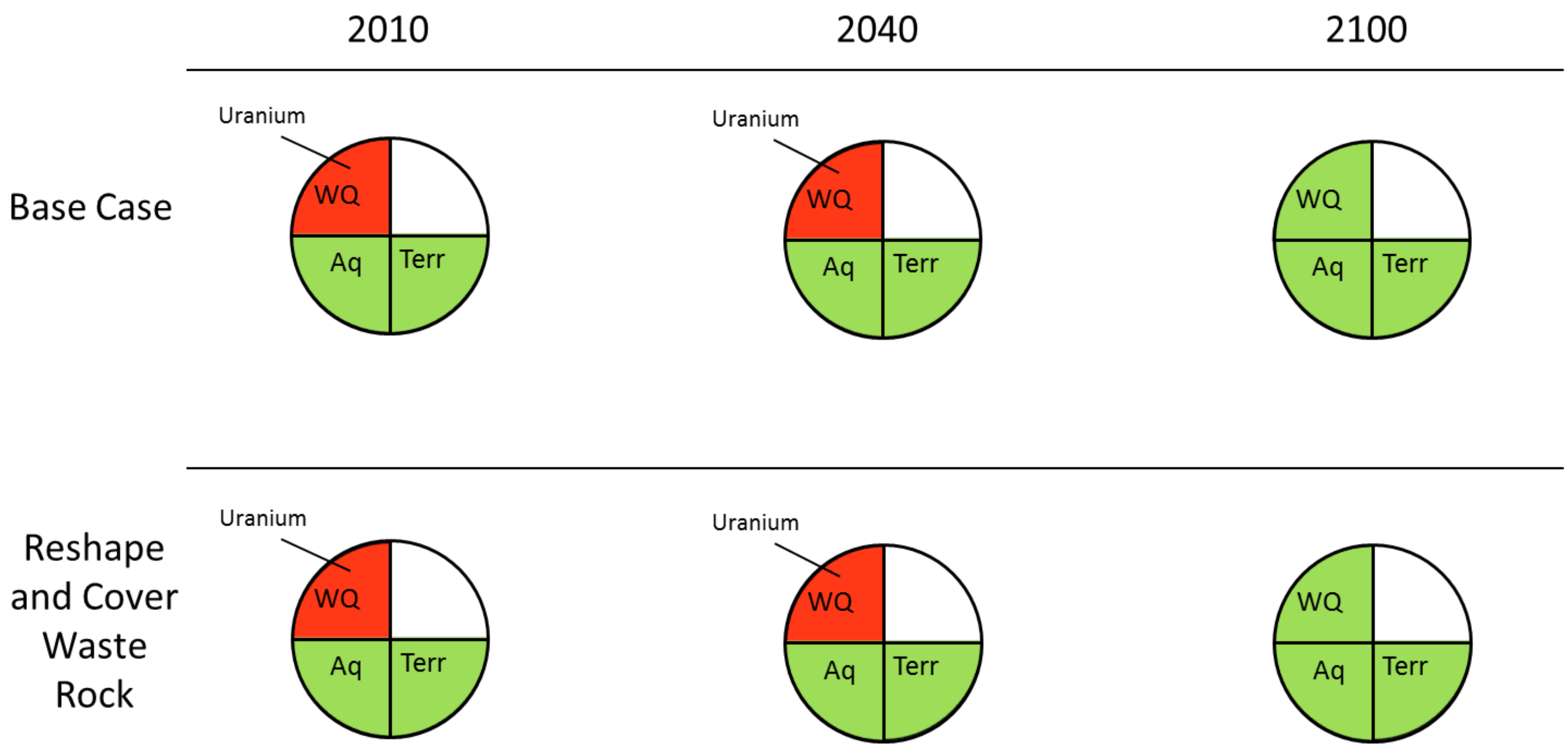
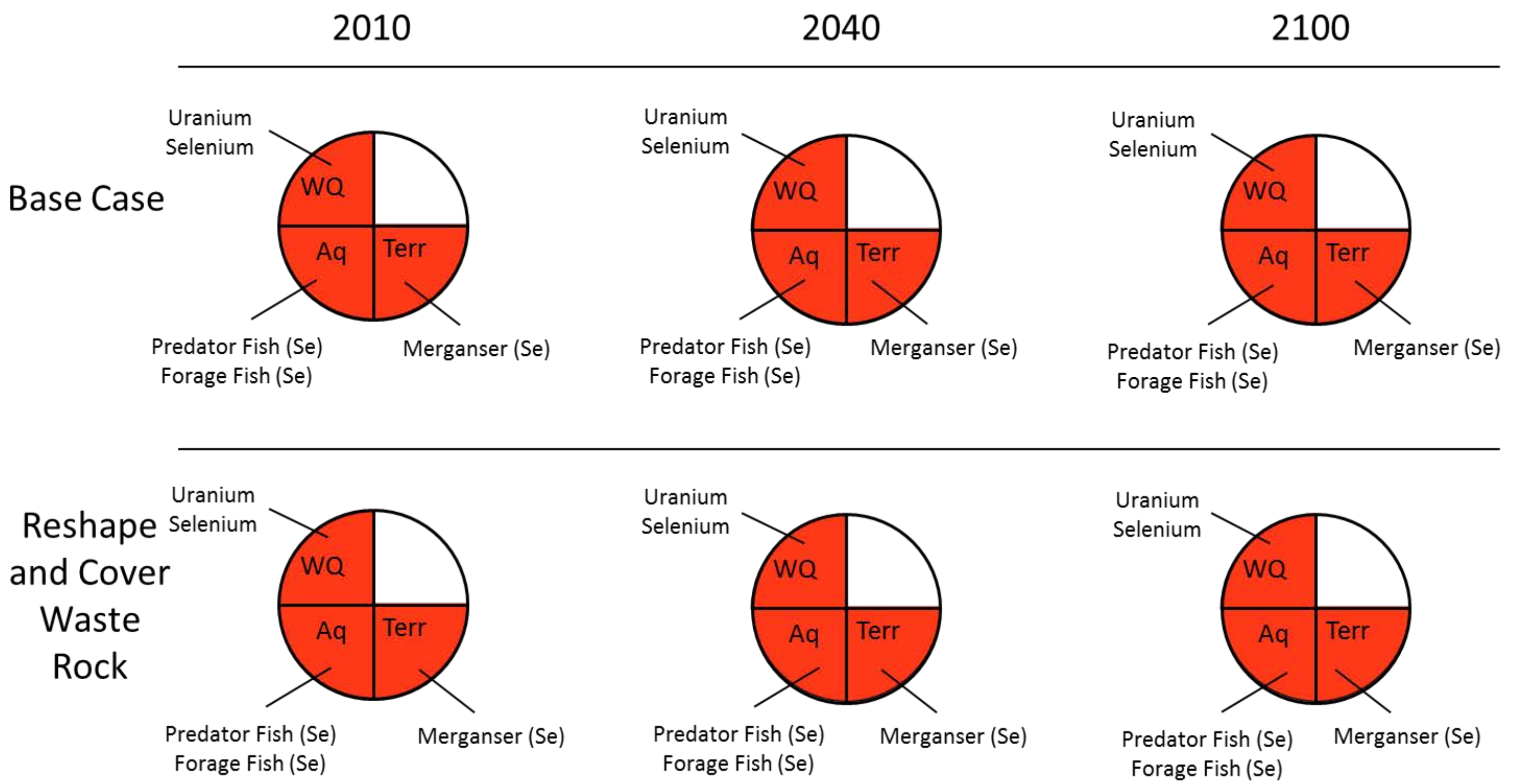


Figure 2.5-5 Summary of Outcomes in Ace Bay, Beaverlodge Lake (Reshape and Cover Fay Waste Rock Pile)



2.5.3.2 Cover Exposed Tailings

This remedial measure involves placing a cover on exposed tailings in the Lower Ace Creek area. Cover systems investigated include a simple sand cover as well as installation of a geo-synthetic/sand cover; in both cases the sandy soil layer is assumed to be 500mm thick.

Areas of tailings within the Lower Ace Creek area can be found near the location of the former Dorrclone plant, within the Ace Uplands and along the former tailings lines. Gamma levels of up to 10 µSv/hr have been observed in very localized areas; it is predicted that either type of cover would be able to reduce this to below 2.5 µSv/hr.

Potential change to downstream water and sediment quality based on covering the exposed tailings in the Lower Ace Creek area were assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- It was conservatively assumed that cover is applied to all tailings within the Lower Ace Creek Area and that this cover would make a significant difference in percolation rates into the tailings in every area.
- Geo-synthetic liner system applied to tailings, which is able to reduce percolation through tailings piles to 5% from 39%
- The annual precipitation rate for the region and base case percolation rate for the waste tailings are discussed in SENES (2012) and were assumed to be 273 mm/a and 39%, respectively.

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 1% and a reduction in uranium load of 4% to the downstream environment.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.5-6 and 2.5-7. Similar to in the case of covering the Fay waste rock pile, very little change is seen to the predicted water quality in Lower Ace Creek and Ace Bay of Beaverlodge Lake as a result of cover application to tailings. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.5-8 and 2.5-9 for Lower Ace Creek and Ace Bay of Beaverlodge Lake as compared to the base case, with no remediation. As can be seen, covering exposed tailings within the Lower Ace Creek area does not change the exceedances predicted in Lower Ace Creek or Ace Bay of Beaverlodge Lake. Although uranium is predicted to be in exceedance of the applicable guidelines in Lower Ace Creek in the first few decades, risk to evaluated receptors are predicted to be below the SI benchmarks throughout the entire period. The results presented are for application of a geo-synthetic liner and if a sand cover is selected instead, the predicted benefit of this activity would be even less.

The cost of applying a cover to the tailings located within the Lower Ace Creek area was estimated by SENES & SRK (2012) to be $5 or $12 million CAD for sand cover and geo-synthetic cover, respectively. These costs include the NPV of a $10,000 CAD per year maintenance cost. If sand cover is placed only on select areas (i.e., easily accessible areas with elevated gamma levels), it is likely to be approximately $500,000 CAD.

Figure 2.5-6 Lower Ace Creek Water Quality Predictions (Cover Exposed Tailings)

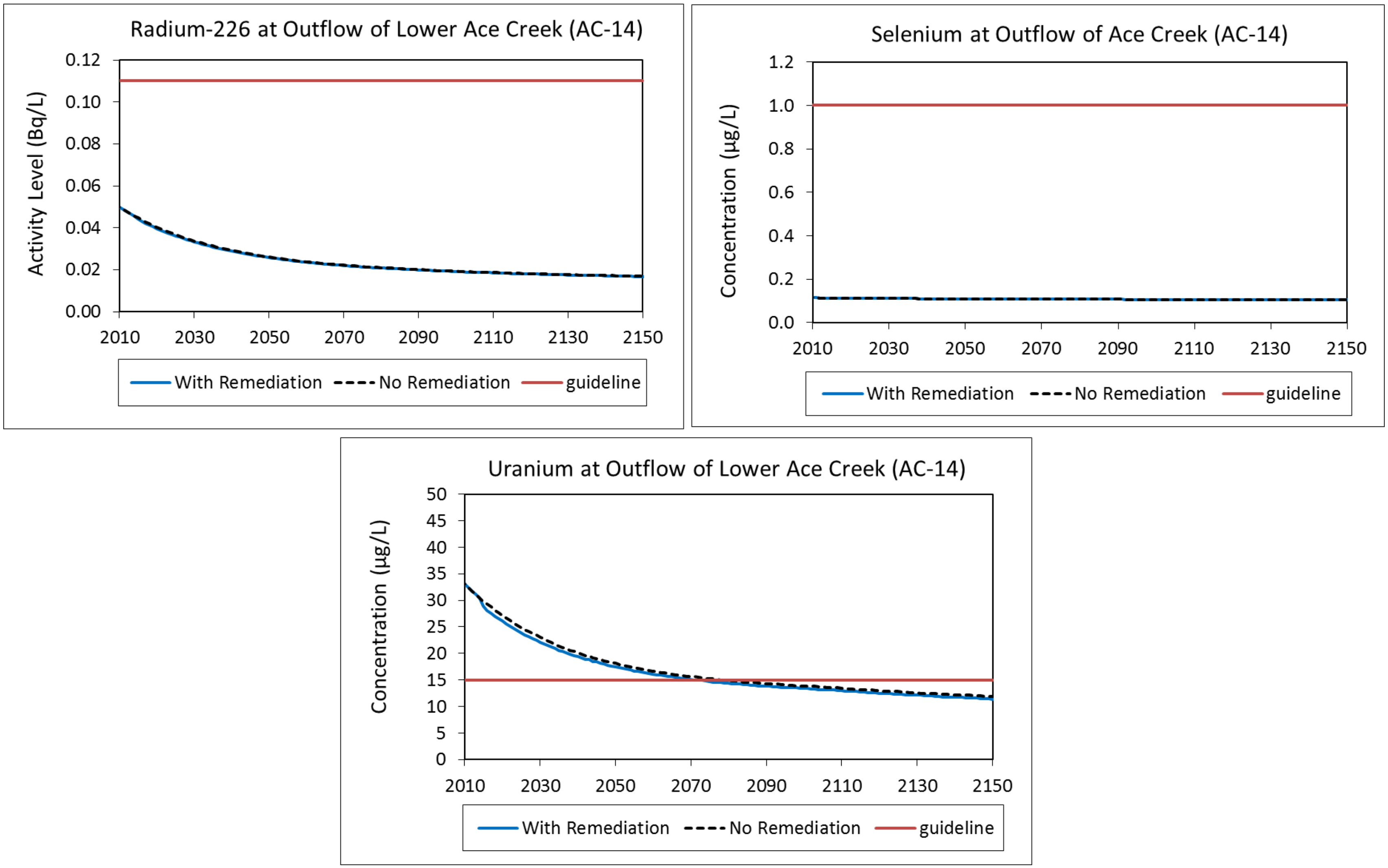


Figure 2.5-7 Ace Bay, Beaverlodge Lake Water Quality Predictions (Cover Exposed Tailings)

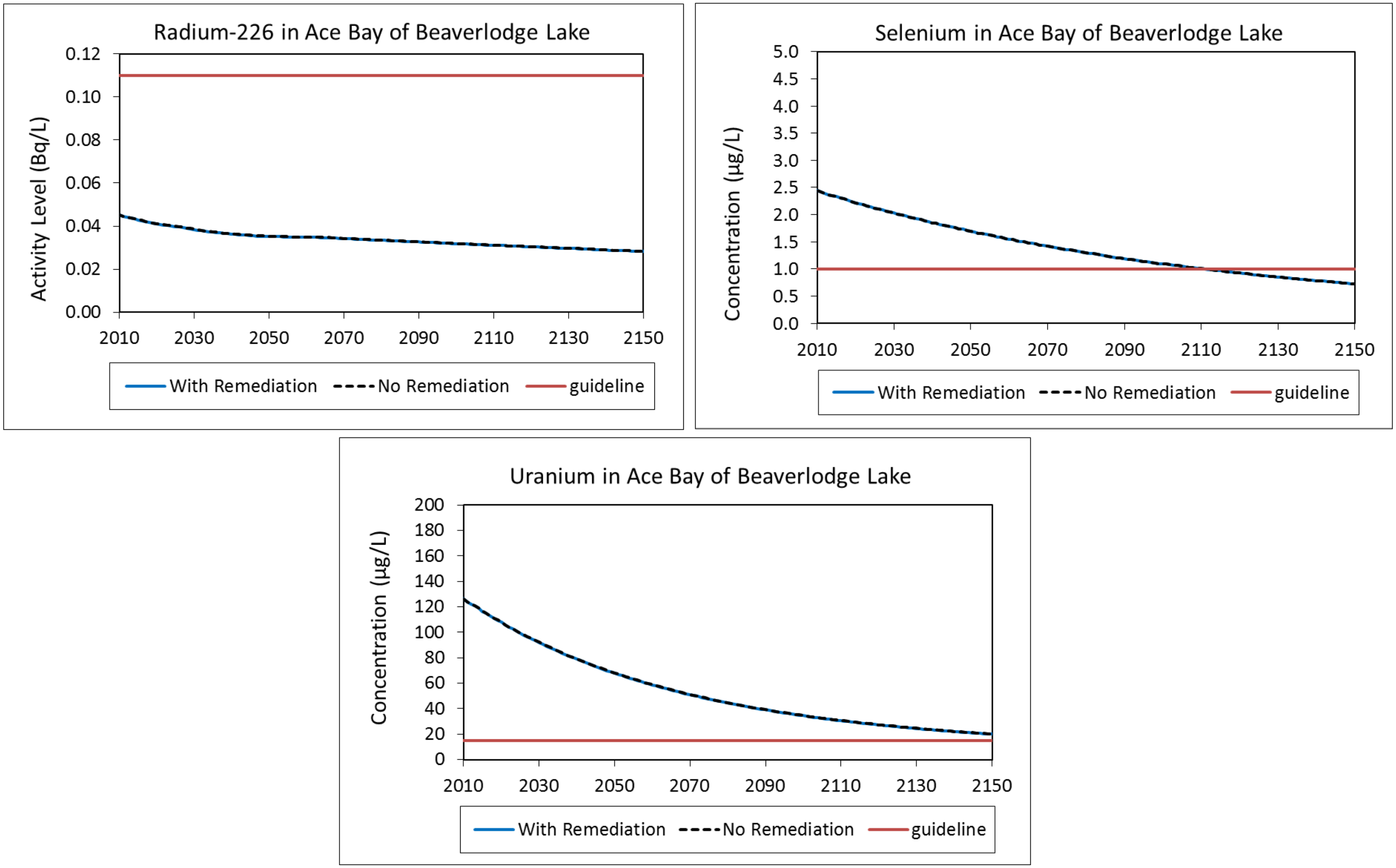


Figure 2.5-8 Summary of Outcomes in Lower Ace Creek (Cover Exposed Tailings)

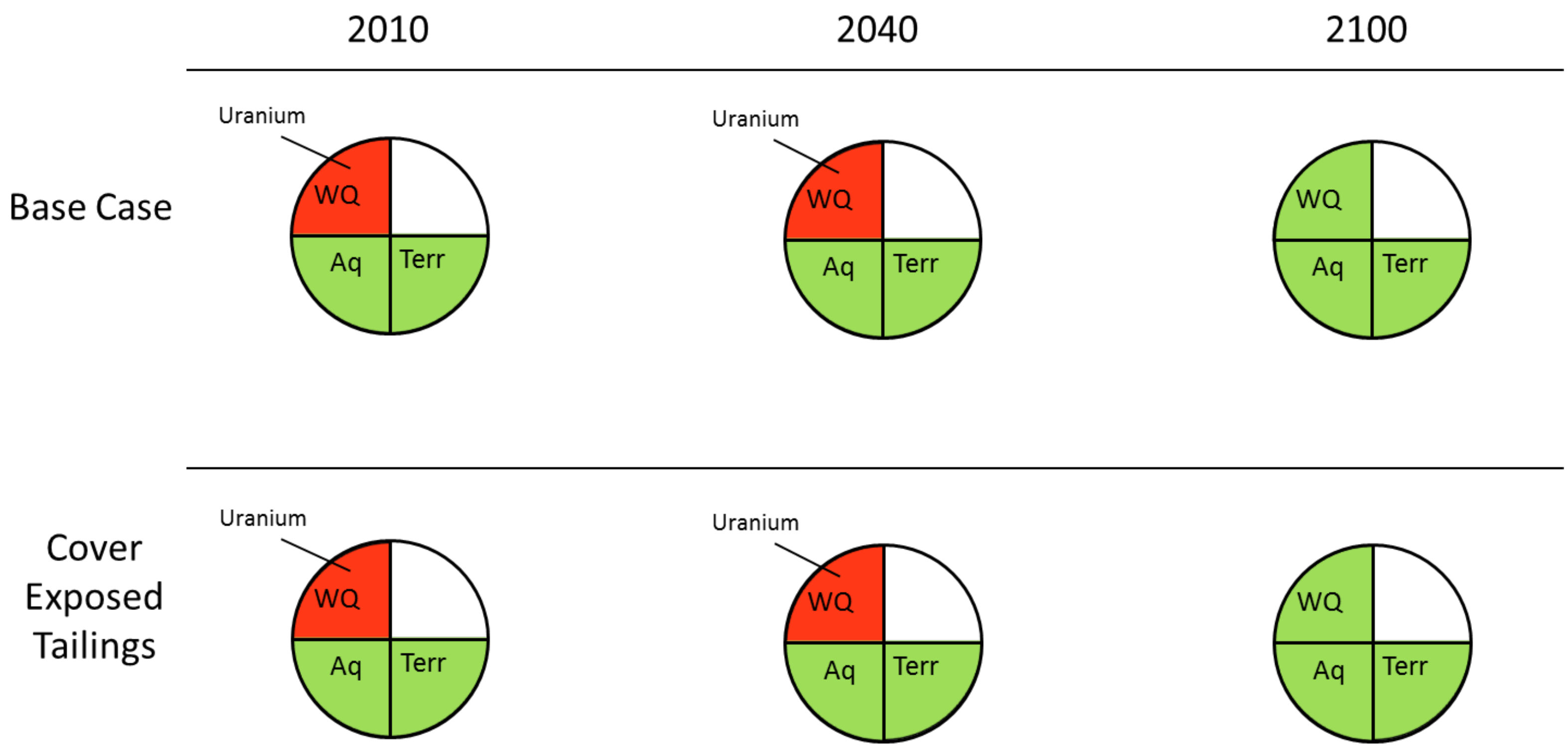
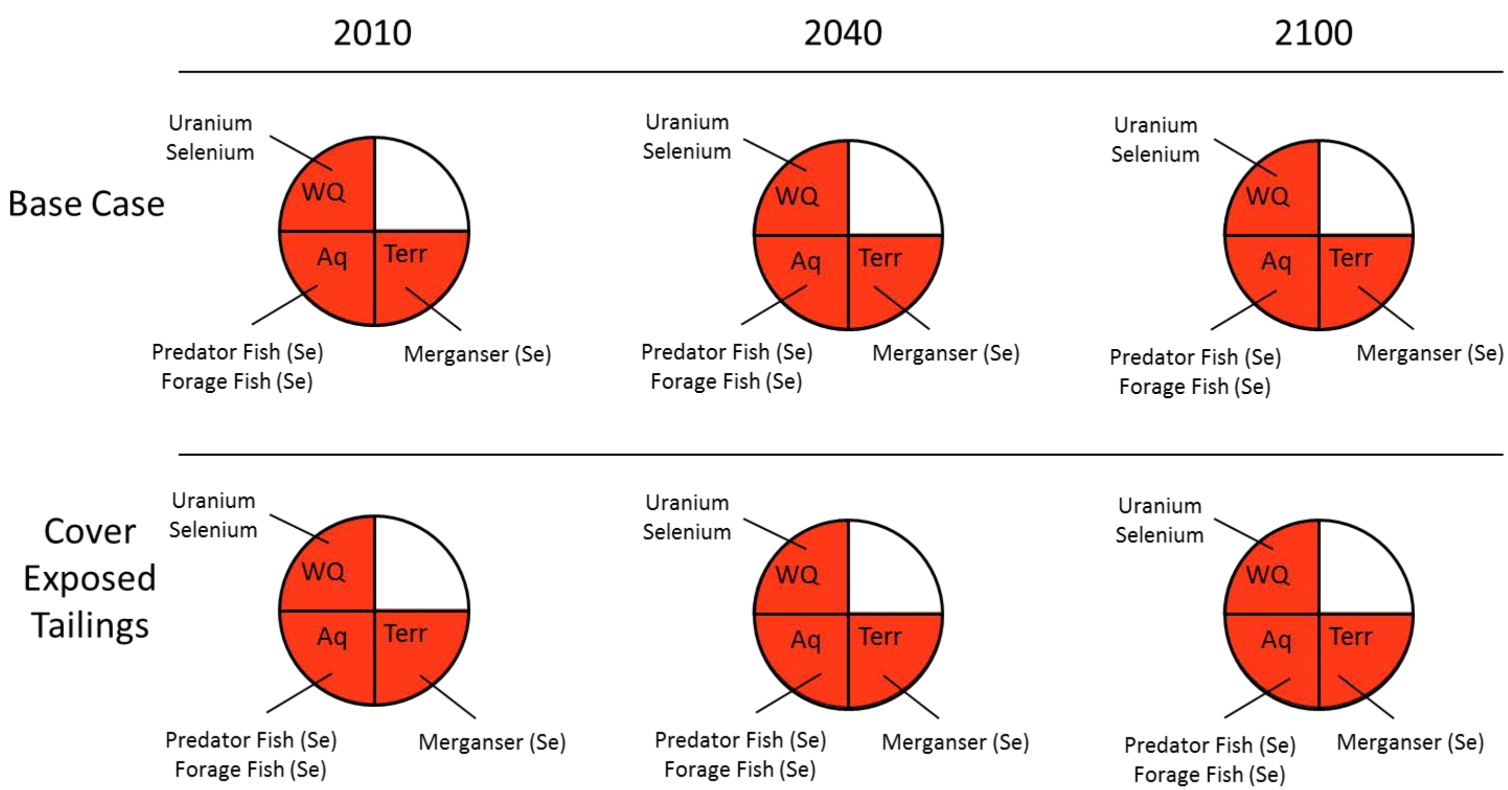


Figure 2.5-9 Summary of Outcomes in Ace Bay, Beaverlodge Lake (Cover Exposed Tailings)



2.5.3.3 Plug Identified Flowing Boreholes

Boreholes in the Lower Ace Creek area were previously identified through extensive GPS aided surveys of the region. The identified boreholes are primarily located in the area where Lower Ace Creek flows into Ace Bay of Beaverlodge Lake. Due to the topographic features in the area, the majority of flow originating from the identified boreholes is expected to flow directly into Ace Bay and not into Lower Ace Creek. There are some boreholes located within the Ace Creek sub-watershed, however, these boreholes have remained dry during past monitoring events. As such, no benefit is expected to Lower Ace Creek and, due to the nature of Ace Bay, no significant benefit is predicted to be realized in Ace Bay as a result of plugging identified boreholes in the Lower Ace Creek area. However, plugging of these identified boreholes is considered to be good engineering practice in the mine closure process.

This activity was completed during in the 2011 and 2012 years with an associated cost of approximately $120,000 CAD. The cost of plugging any additional flowing boreholes discovered in the Lower Ace Creek Mine area on a one off basis is estimated to be $75,000 CAD per borehole.

2.5.3.4 Treatment of Mill Seep for Uranium Removal

This activity involves the installation of a passive treatment system. This system consists of a collection trench to consolidate the numerous seeps into a single stream and a passive sulphate reducing bio-reactor. The vertical bioreactor includes a 2600 m^2 reactor and a 520 m^2 passive aerobic polishing pond. It was assumed that the reactor will require replacement every 10 years with the existing reactor decommissioned in place with the inlet and outlet pipes removed.

Potential effects of treating the Mill seep for uranium removal were assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- It was assumed that 95% of the load from the Mine and Mill originates from the Mill area while the remaining 5% is due to flow from underground mine workings through unidentified boreholes and other mine openings. This breakdown is discussed in the Beaverlodge QSM Report (SENES 2012a). Although this division is based on measured flows and concentrations seen in flowing boreholes and seeps in the Lower Ace Creek area, there is uncertainty regarding the exact breakdown between these two sources.

- It was assumed that 100% of the load to Lower Ace Creek originating from the Mill area surfaces in the observed seeps.
- It was assumed, most likely optimistically, that a collection efficiency of 85% is achievable; that is 85% of the seep flow can be captured.
- Bioreactor designed for 3 L/s throughput able to handle all collected flow
- Passive treatment system is able to achieve concentrations of:
    - Uranium: 10 µg/L
    - Selenium: 1 µg/L

Over the first 50 years of implementation, these assumptions result in a predicted reduction in uranium load of 18% from 366 kg/yr to 301 kg/yr and a reduction in selenium load of 57% from 1.1 kg/yr to 0.5 kg/yr to the downstream environment.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.5-10 and 2.5-11. While a reduction in water uranium levels is seen in the immediate area (Lower Ace Creek), these results are not translated into predicted improvements in the downstream environment (Ace Bay of Beaverlodge Lake). A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.5-12 and 2.5-13 for Lower Ace Creek and Ace Bay of Beaverlodge Lake as compared to the base case, with no remediation. As can be seen, implementation of this water treatment does not change the exceedances predicted in either Lower Ace Creek or Ace Bay. Although uranium is predicted to be in exceedance of the applicable guidelines in Lower Ace Creek, risk to the evaluated receptors are not anticipated to be above the applicable SI benchmarks.

The cost of installing, operating and maintaining a sulphate reducing passive bioreactor in the Lower Ace Creek area for treatment of seep flow was estimated by SENES & SRK (2012) to be approximately $4.4 million CAD. This cost includes the NPV of an annual operation and maintenance cost of approximately $100,000 CAD.

Figure 2.5-10 Lower Ace Creek Water Quality Predictions (Treat Mill Seep for U Removal)

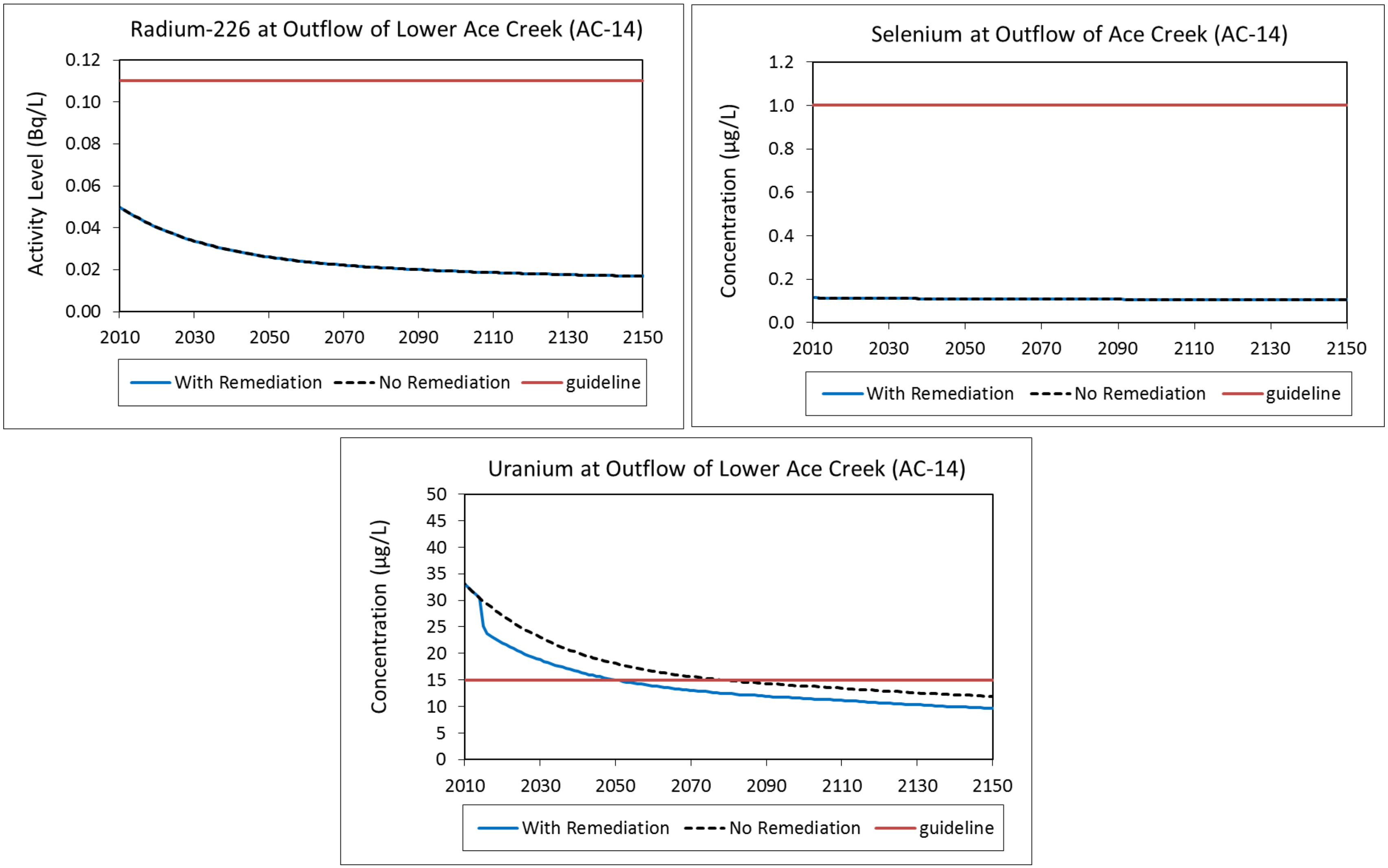


Figure 2.5-11 Ace Bay of Beaverlodge Lake Water Quality Predictions (Treat Mill Seep for U Removal)

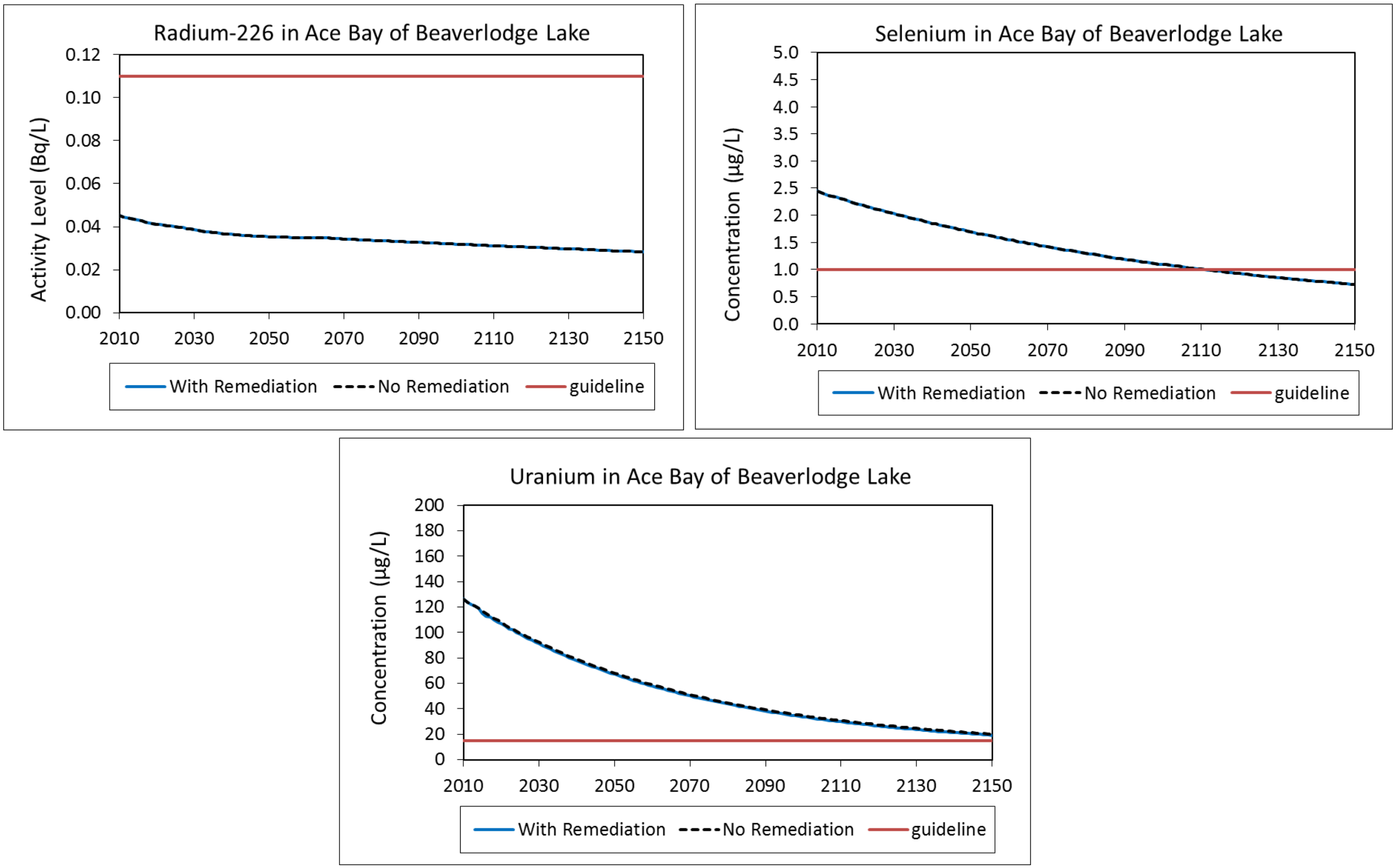


Figure 2.5-12 Summary of Outcomes in Lower Ace Creek (Treat Mill Seep for U Removal)

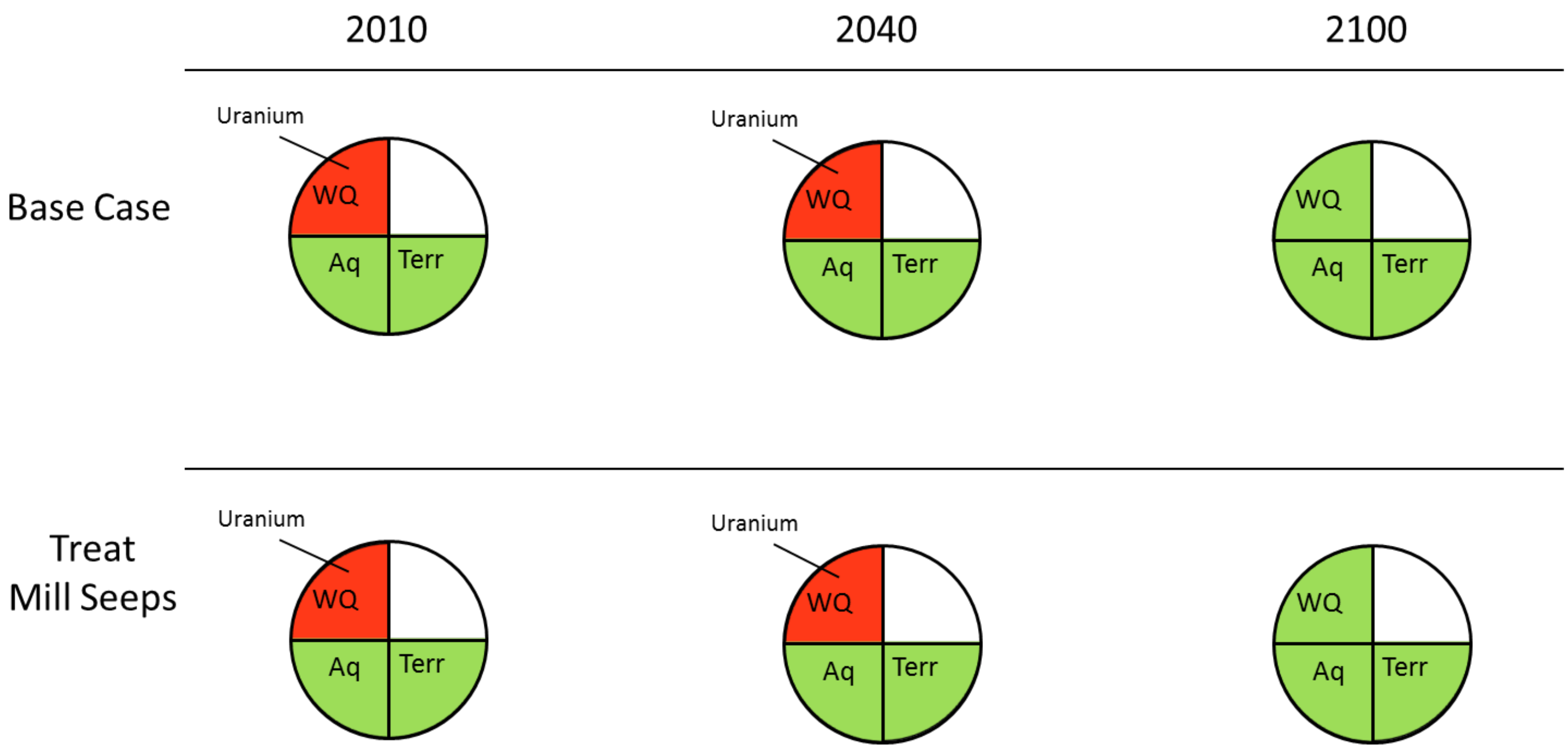
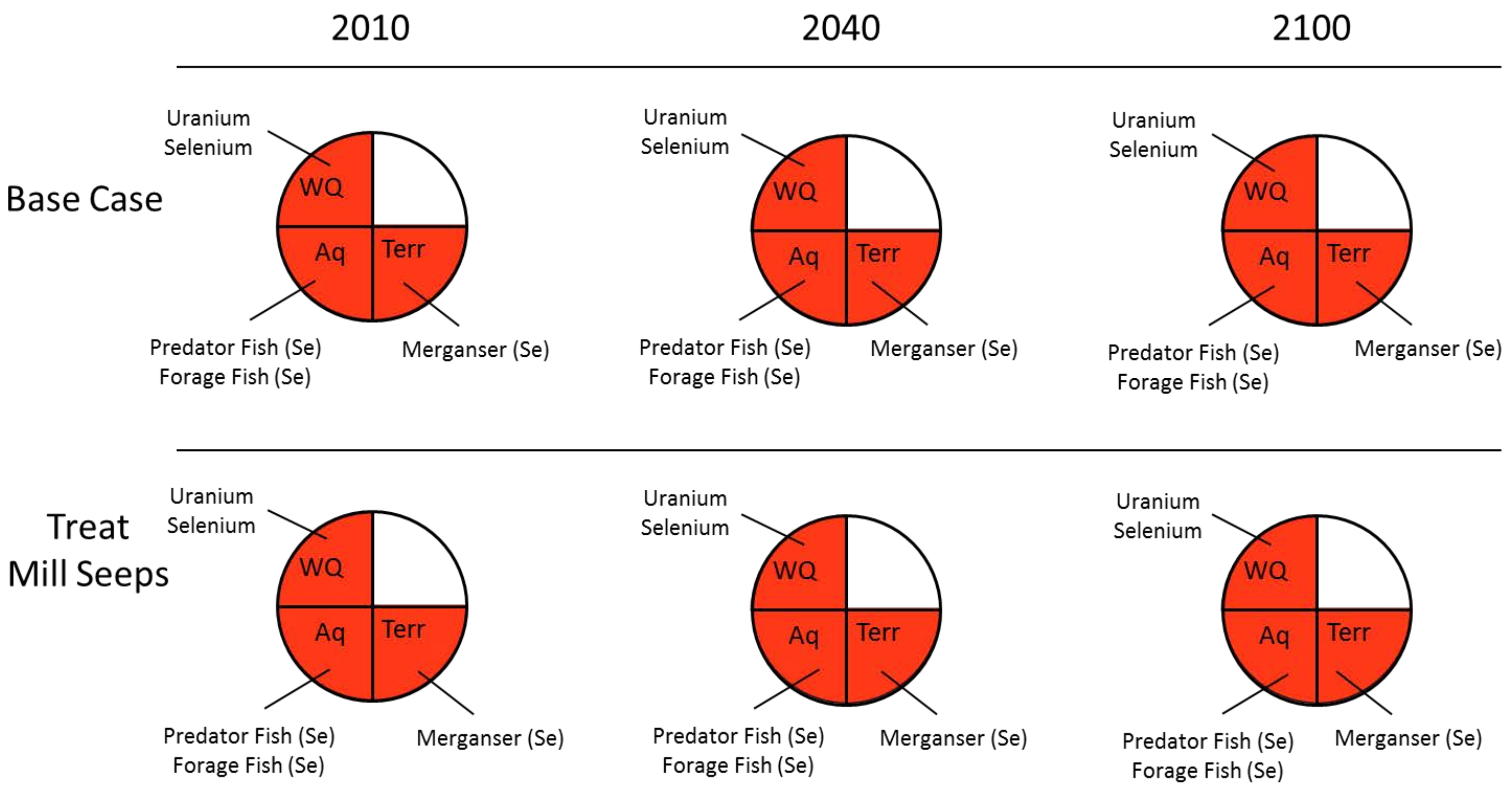


Figure 2.5-13 Summary of Outcomes in Ace Bay of Beaverlodge Lake (Treat Mill Seep for U Removal)



2.5.3.5 Excavate Waste Rock Pile and Plug Additional Boreholes and Other Conduits for Mine and Mill Water Flow

This activity involves excavating and consolidating 5% (~150,000 m^3) of the Fay waste rock pile in the region around the former Mill site to allow for the identification of additional boreholes or mine openings through which contaminated mine and mill water could potentially be flowing and plugging them to reduce the outflow. The success and cost of this activity are uncertain as the location of boreholes and other conduits for contaminated water flow and the associated flow rates are unknown.

Potential change to environmental conditions based on plugging Lower Ace Creek area mine and mill openings was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- It is assumed that 95% of the load from the Mine and Mill to Lower Ace Creek originates from the Mill area while the remaining 5% is due to flow from underground mine workings through unidentified boreholes and other conduits for mine water flow. This breakdown is discussed in the Beaverlodge QSM Report (SENES 2012a). Although this division is based on measured flows and concentrations seen in flowing boreholes and seeps in the Lower Ace Creek area, there is uncertainty regarding the exact breakdown between these two sources.
- It was assumed, most likely optimistically, that these activities will result in a 50% reduction in combined flow from the underground mine workings and the mill area.

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 17% from 5.3×10^5 kBq/yr to 4.4×10^5 kBq/yr and a reduction in uranium load of 11% from 366 kg/yr to 324 kg/yr to the downstream environment. It is important to note that, given the uncertainty regarding effectiveness of this remedial activity, the predicted benefit of this measure cannot be quantified with accuracy and that these predictions may be a great overestimate of the possible benefit. In addition, the model predictions do not attempt to account for the potential negative impacts of exposing additional waste rock to weathering during implementation of this remedial measure.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.5-14 and 2.5-15. Very little improvement to water quality is seen in the immediate area (Lower Ace Creek) or the downstream environment (Ace Bay of Beaverlodge Lake) as a result of this remedial measure. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.5-16 and 2.5-17 for Lower Ace Creek and Ace Bay of Beaverlodge Lake as compared to the base case, with no remediation. As can be seen, plugging additional boreholes and other mine/mill openings does not change the exceedances predicted in Lower Ace Creek or Ace Bay. Although uranium is predicted to be in exceedance of the applicable guidelines in Lower Ace Creek, predicted risk to the evaluated receptors are not anticipated to exceed the SI benchmarks.

Costs of excavating a portion of the Fay waste rock pile to plug boreholes and other mine openings was estimated by SENES & SRK (2012) to be approximately $6.6 million CAD plus approximately $75,000 CAD for each additional borehole discovered. Costs for plugging any other flowing mine openings are uncertain and will depend on the individual location and nature of the opening.

Figure 2.5-14 Lower Ace Creek Water Quality Predictions (Excavate to Plug Lower Ace Creek Area Mine/Mill Openings)

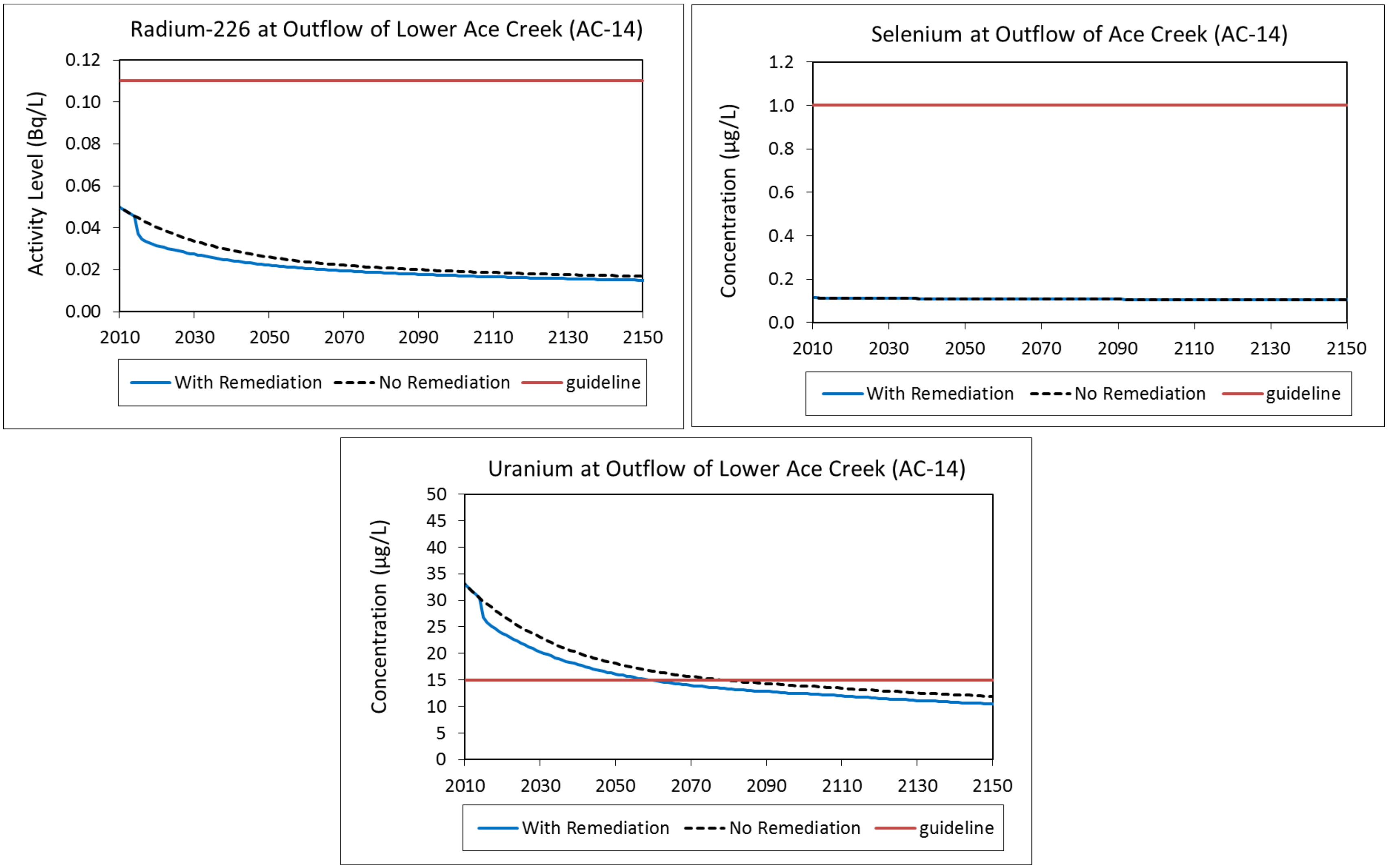


Figure 2.5-15 Ace Bay of Beaverlodge Lake Water Quality Predictions (Excavate to Plug Lower Ace Creek Area Mine/Mill Openings)

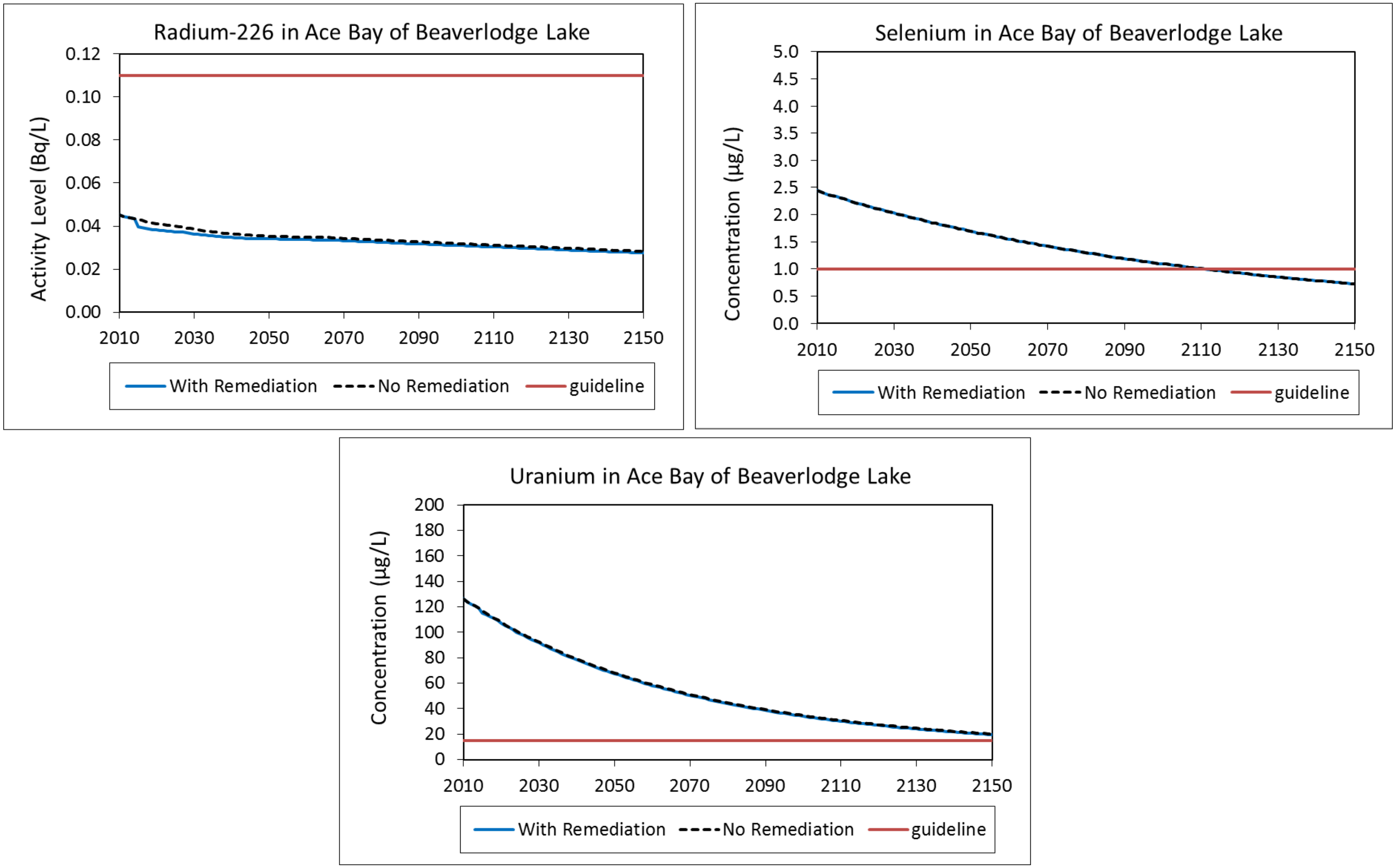


Figure 2.5-16 Summary of Outcomes in Lower Ace Creek (Excavate to Plug Lower Ace Creek Area Mine/Mill Openings)

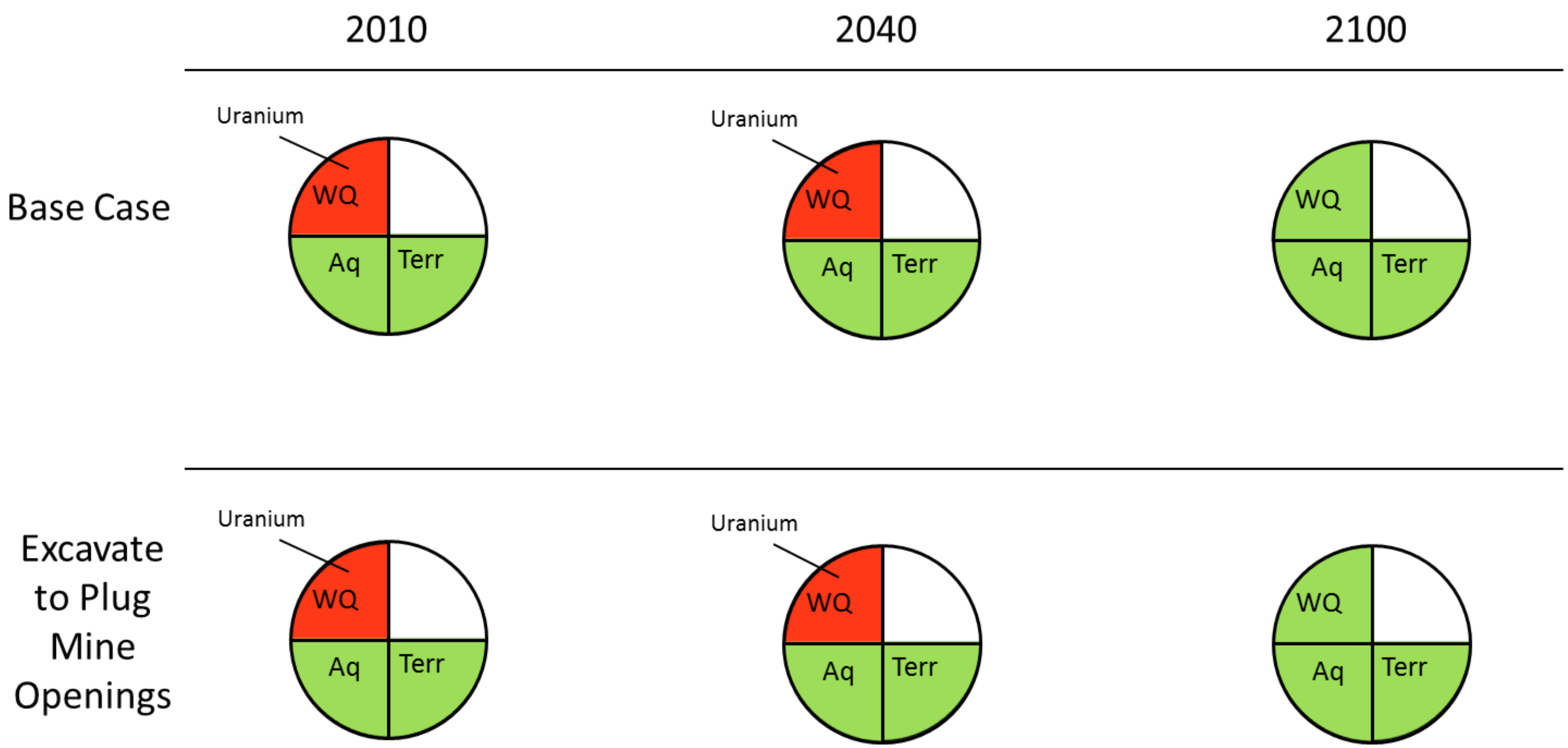
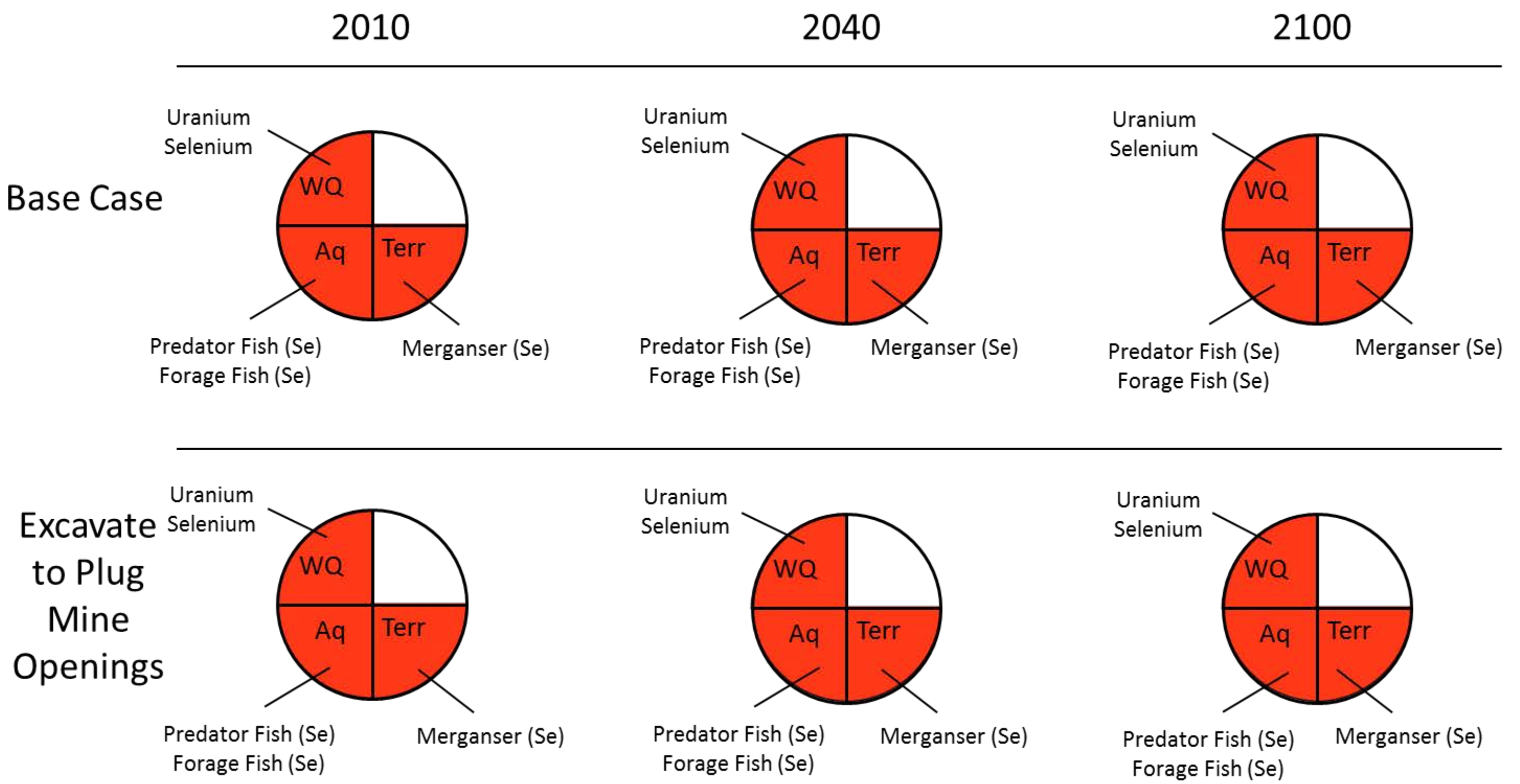


Figure 2.5-17 Summary of Outcomes in Ace Bay of Beaverlodge Lake (Excavate to Plug Lower Ace Creek Area Mine/Mill Openings)



2.5.3.6 Replacement of Caps on Vertical Openings

This activity involves replacing the original concrete caps on all vertical mine openings in the Lower Ace Creek area with engineered caps, which may include concrete or stainless steel. The decommissioning documentation (MacLaren Plansearch 1987) identifies nineteen openings in the Lower Ace Creek area; three of these openings are indicated in Figure 2.5-1. Further investigation work may be required to locate the other vertical mine openings.

It is not anticipated that this activity will result in any change to the immediate or downstream environments because no significant water infiltration of discharge is expected to be occurring through these openings; however, it is included for discussion as it is considered to be good engineering practice and will improve the long-term safety of the site for humans and wildlife frequenting the area. It is assumed that these engineered caps would require routine assessment of condition after a period of between 75 and 100 years and more frequently immediately following installation. For the calculation of future monitoring and maintenance costs it is assumed that the caps will require replacement every 100 years although this is anticipated to be overly conservative.

The cost of replacing these vertical mine opening caps was estimated to be approximately $70,000 (SENES & SRK 2012) for each cap based on previous experience as well as an additional cost of approximately $70,000 for mobilization, de-mobilization, site preparation and site clean-up.

2.5.3.7 Plug Identified Non-flowing Boreholes

This activity involves injecting grout into all identified non-flowing boreholes in the Lower Ace Creek area. This activity is considered to be good engineering practice as it reduces the risk that these openings might serve as conduits for mine water in the future.

Plugging non-flowing boreholes will not affect the immediate or downstream environments.
Estimated costs of plugging identified non-flowing boreholes are approximately $10,000 CAD.

2.5.4 Lower Ace Creek Selection of Remedial Activities

In addition to predicted changes to the environment as assessed by the Beaverlodge QSM (SENES 2012a) and estimated costs of assessed activities (SENES & SRK 2012), opinions expressed during the Beaverlodge Remedial Option Workshop (ASKI, SENES & SRK 2012) can be used as additional information to help inform the remedial activity evaluation process. Outcomes from these three sources are discussed below. In addition, the costs and benefits for each of the remedial measures considered for the Lower Ace Creek area are summarized in Table 2.5-2. For each remedial activity expected change to exceedances, predicted reduction in loads, estimated costs as well as calculated cost per unit reduction are presented.

Table 2.5-2 Summary of Predicted Effects of Remedial Activities, Lower Ace Creek Area

Remedial Measure	Change to Water Quality or Human/Eco Risk?[a,b]	Reduction in Load to Downstream Environment[c]			Estimated Costs (CAD)	Cost per Unit Reduction[c]			Comments
		Ra-226 (MBq/yr)	Se (kg/yr)	U (kg/yr)		Ra-226 (CAD/kBq/yr)	Se (CAD/g/yr)	U (CAD/g/yr)	
Reshape and cover Fay waste rock pile	no change to exceedances	3.3 (0.6%)	-	7.9 (2%)	$13,000,000 to $28,000,000	8,620	-	3,540	-predicted effect on contaminant loads downstream of Lower Ace Creek insignificant
Place cover on exposed Tailings	no change to exceedances	6.1 (1%)	-	13.4 (4%)	$500,000 to $11,700,000	1,920	-	870	- predicted effect on contaminant loads downstream of Lower Ace Creek insignificant -reduces the potential for gamma exposure by receptors frequenting the site
Plug identified Lower Ace Creek area flowing boreholes	no change to exceedances	-	-	-	$120,000 (already completed)	-	-	-	-predicted effect on contaminant loads downstream of Lower Ace Creek insignificant -good engineering practice
Treat Mill seep for U and Se removal	no change to exceedances	-	0.6 (57%)	65.4 (18%)	$4,400,000	-	7,300	67	-success of activity uncertain but could lead to faster recovery of the uranium level in Lower Ace Creek -predicted effect on contaminant loads downstream of Lower Ace Creek insignificant -requires ongoing maintenance of the bioreactor
Excavate Fay waste rock and plug additional flowing boreholes and conduits for mine/mill water flow	no change to exceedances	93 (17%)*	-	41.5 (11%)*	$6,600,000 plus additional cost of plugging boreholes and openings	71+*	-	160+*	-success of activity uncertain -limited knowledge of location and flows of streams within the Fay waste rock pile -predicted effect on contaminant loads downstream of Lower Ace Creek insignificant
Replace caps on vertical mine openings	no change to exceedances	-	-	-	$1,400,000 plus additional cost to locate remaining openings	-	-	-	-good engineering practice -reduces future hazard to those using the site -no predicted effect on contaminant loads
Plug identified non-flowing boreholes	no change to exceedances	-	-	-	$10,000	-	-	-	-no effect on contaminant loads -good engineering practice

Notes:

[a] for the base case scenario (no remediation), there is no predicted risk to any assessed ecological receptors in Lower Ace Creek throughout the modeled period.

[b] human receptors not assessed in Lower Ace Creek or Ace Bay areas.

[c] load reductions estimated over the first 50 years after implementation

* Actual benefits and associated costs per unit reduction may vary greatly from these values due to the uncertainty regarding effectiveness of implementing this remedial activity

Reshaping and cover of the Fay waste rock pile is seen to have very little impact on the immediate and downstream environments. This measure was discussed during the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012) and the general opinion was that the predicted improvement in water quality does not justify the cost.

Similar to options discussed above of covering the Fay waste rock pile, covering tailings in the Lower Ace Creek area are seen to have a minimal effect on water quality in the immediate and downstream environment. For this reason, this measure was not included in any remedial scenarios discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). It should be noted that, while no significant benefit is seen to the aquatic environment, covering exposed, non-vegetated tailings in easily accessible areas may reduce gamma exposure to humans and animals frequenting the site. Disturbing re-vegetated areas in order to apply a cover would likely result in increased environmental harm and release of contaminants from the disturbed tailings areas.

Although plugging currently identified boreholes likely has no impact on the Lower Ace Creek area or downstream, it is considered to be good engineering practice to plug all identified boreholes during remedial works. This activity was discussed during the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012) and, in general, stakeholders were in favor of this activity as it was seen as taking clear action on point sources with relatively low costs.

Treatment of mill seep for uranium and selenium removal is predicted to result in reductions to uranium levels in Lower Ace Creek; however, these benefits are not seen in predictions for Ace Bay of Beaverlodge Lake. This activity was included in a number of scenarios discussed during the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). Stakeholders raised concerns about the technical feasibility of applying a passive treatment system in a cold climate such as this on the existing terrain (primarily bedrock). It was also noted that this passive bioreactor would require ongoing maintenance and there would be issues associated with excavation and disposal of contaminated sludge from the reactor every 10 years or so.

The feasibility of excavation of the Fay waste rock pile to identify and plug additional boreholes and other openings through which mine and mill water could flow is uncertain. Applying the assumptions listed in the previous section, there is predicted to be very little benefit to the immediate or downstream environment. There was concern from many of the stakeholders at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012) that this activity would cause a significant disturbance in the Lower Ace Creek area, remobilizing constituents within the waste rock while the success of stopping the contaminated flow is uncertain and the cost relatively high.

Replacing the caps on the vertical mine openings in the area is not expected to influence environmental conditions in the area, however, it is considered to be good engineering practice as it reduces the potential for cap failure in the future. Similarly, plugging non-flowing boreholes in the area will not benefit the environment but is considered to be a good engineering practice. These activities will also prepare the site for transfer into the provincial IC Program.

Based on the discussion presented above and in the previous section, the recommended course of action developed by Cameco for the Lower Ace Creek area is to plug identified boreholes (flowing and non-flowing), cover easily accessible exposed tailings with a sand layer, replace the caps on all vertical mine openings and continue to monitor the area to ensure that recovery is progressing as expected. The other considered activities are not recommended in part due to the cost of implementing the activities in relation to the predicted benefit on the downstream environment.

2.6 FULTON CREEK WATERSHED

The Fulton Creek Watershed consists of a number of water bodies. The main water bodies are Fulton Lake, Fookes Reservoir, Marie Reservoir, and Greer Lake. Fresh water flows into Fookes Reservoir from Fulton Lake while water exiting Fookes Reservoir flows into Marie Reservoir and then through a meadow (known as Meadow Fen) to Greer Lake. In addition the small catchment which houses Unnamed and Minewater reservoirs flows through the Meadow Fen into Greer Lake. Water exiting the Fulton Creek Watershed through Greer Lake flows into Fulton Bay of Beaverlodge Lake. The Fulton Creek Watershed is shown in Figure 2.6-1.

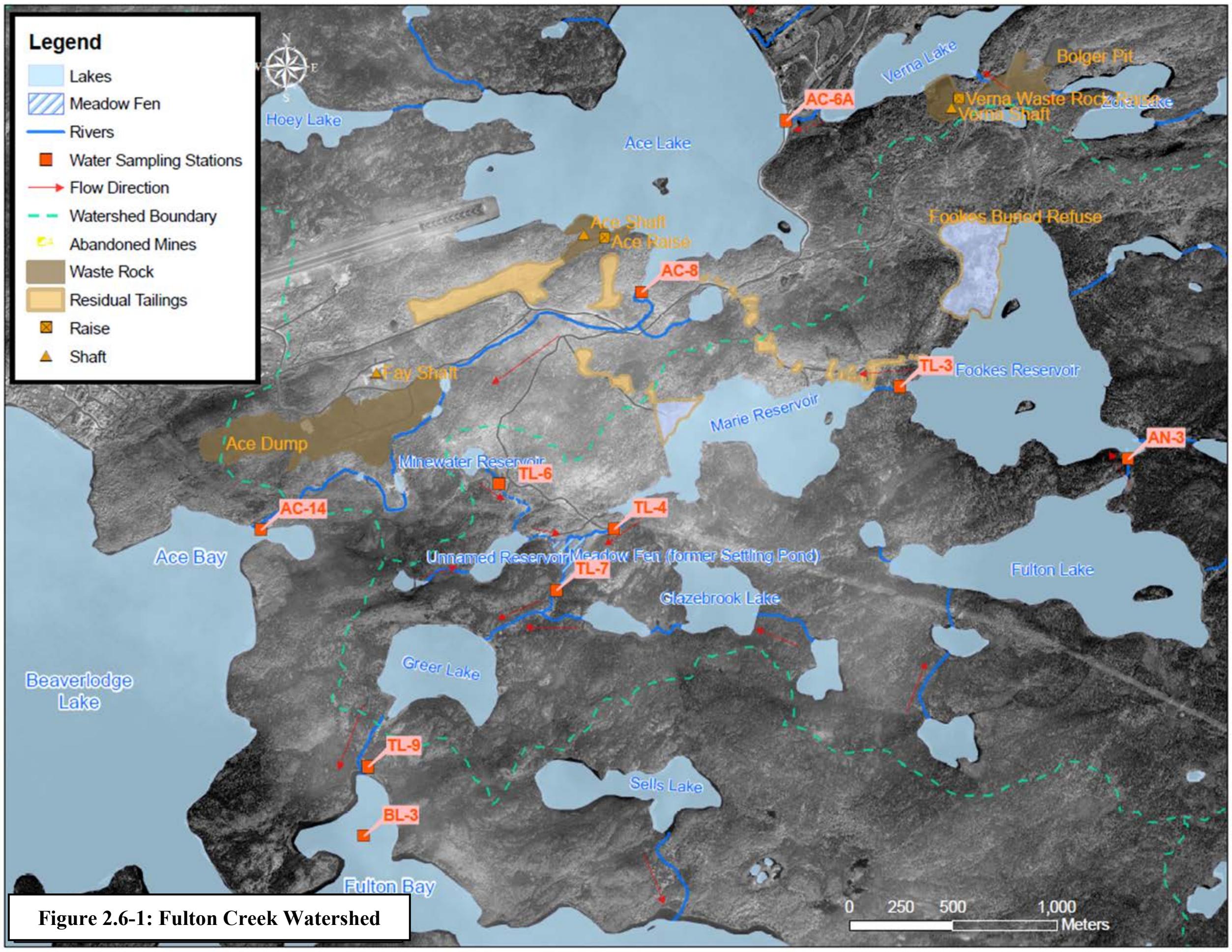


Figure 2.6-1: Fulton Creek Watershed

2.6.1 Fulton Creek Watershed Features

The Fulton Creek watershed contains the Beaverlodge Tailings Management Area (BTMA). Tailings were deposited into the BTMA from the commencement of milling operations in 1953; however, treatment of the tailings effluent did not commence until twenty-three years later in 1976. During milling operations the BTMA, which is shown in Figure 2.6-1, consisted of

(1) two reservoirs (Fookes Reservoir and Marie Reservoir) that were used for tailings solid settling; (2) a man-made pond (Meadow Settling Pond, now Meadow Fen) in which particulate and precipitated radium was settled following the addition of barium chloride at the Marie Reservoir treatment plant (post 1976); and, (3) a third reservoir (Minewater Reservoir) that was initially used for tailings deposition (in 1953) and later as a settling pond for treated mine water (in the 1970's). The natural discharge from Minewater Reservoir was to the Ace Creek watershed but it was diverted to the Fulton Creek watershed in the 1970s.

As mentioned above, tailings were deposited into Minewater Reservoir beginning in 1953, but the line was moved to Marie Reservoir in 1954 as Minewater Reservoir had insufficient storage capacity. Due to poor settling characteristics of tailings in Marie Reservoir, which resulted in tailings migration downstream to Beaverlodge Lake, the discharge point was moved to Fookes Reservoir in 1957. Approximately 10.1 million tonnes of tailings were produced during the life of the facility. Fookes Reservoir was the primary surface tailings disposal location (approximately 6 million tonnes); however, Marie Reservoir received 170,000 tonnes and 101,000 tonnes were placed in Minewater Reservoir. The remainder of the tailings (42%) were placed underground as mine backfill. A tailings beach developed at Fookes Reservoir and at Marie Reservoir. At shutdown, the beach covered approximately 7% of the original lake surface at Fookes Reservoir and 5% at Marie Reservoir.

A number of flow changes were made in the area during operations. Dams were constructed at the outlets of Fookes and Marie reservoirs in 1969 and 1971, respectively, which allowed flow regulation using stop-log overflow structures. The natural drainage of Minewater Reservoir was toward Ace Creek, but a dam was constructed in 1971 that re-directed the flow towards Unnamed Reservoir then the Meadow area in the Fulton Creek system. The Meadow Settling Pond itself was created through the construction of a dam in 1976. Reclamation activities at closure included: removal of man-made structures; covering of accessible exposed tailings with waste rock; removal of tailings from the inlet and outlet channels of Marie Reservoir and placement in the deep part of the reservoir; removal of tailings and chemical sludge from Minewater Reservoir, which were placed in the Ace/Fay raise and the Ace Shaft; lowering of the water level within Minewater Reservoir through a blasted channel allowing water to flow to Unnamed Reservoir and Meadow Fen; and, lowering of the water level with removal of chemical sludge from the Meadow Settling Pond with disposal down the Fay Shaft.

Monitoring of water quality in the Fulton Creek watershed has been carried out on a routine basis for many years at several locations (see Figure 2.6-1). Station TL-7, located at the downstream end of the BTMA, is the designated compliance station on the Fulton Creek drainage. The dam structure at TL-7, complete with stop logs, remains in place although the volume of water held behind the structure is low.

2.6.2 Fulton Creek Watershed Assessment of Potential Risks

In order to select remedial measures, the potential risks that various features within the Fulton Creek Watershed may pose to the environment and members of the public accessing the site were assessed. Site aspects examined included mining geotechnical; surface water; contaminated substrate; air, radon and gamma; terrestrial and aquatic vegetation; and risk communication. When determining a relative risk rating for each site element likelihood of the event occurring as well as the consequence of that event were considered. The resulting relative risk estimates for the Fulton Creek Watershed are shown in Table 2.6-1.

Table 2.6-1 Summary of Estimated Risks, Fulton Creek Watershed

Aspect	Specific Location	Site Element	Current Risk Registry		Risk Endpoints		References
			Event	Effect	Environment Risk	Public Health and Safety Risk	
Mining Geotechnical	-	-	None identified	-	-	-	Screening Level Risk Assessment, Cameco 2010b.
Surface Water (including Surface Tailings)	**Surface Tailings**	**Tailings Deltas**	Infiltration and subsurface contribution to surface water quality	impact on water quality	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009.
	Fulton Creek Area	**Engineered Dam Structures in the Fulton Creek Watershed**	Structure failure and release of water to downstream	Impact on water quality downstream in the Fulton Creek Watershed and/or Beaverlodge Lake	**ML**	**L**	Screening Level Risk Assessment, Cameco 2010b.
		Fulton Creek Water	Discharge from Greer Lake to downstream waters	Impact on Beaverlodge Lake water quality	**ML**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009.
Contaminated substrate	**General**	**Substrate**	Contaminant release from subaqueous tailings and sediments	Impact on Fulton Creek Watershed water quality	**MH**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009. Aquatic Macrophyte Sampling Program. CanNorth 2011a. Minewater Reservoir Aquatic Investigations. CanNorth 2010.
			Accumulation of Ra-226 in sediment	Impact on Fulton Creek Watershed water quality	**MH**	**ML**	
Air, Radon and Gamma	**General**	**Tailings Covers**	Cover failure and dusting of tailings in the Fookes delta	Inhalation exposure for wildlife and human	**ML**	**L**	Screening Level Risk Assessment, Cameco 2010b.
			Cover failure and dusting of tailings in the Marie delta	Inhalation exposure for wildlife and human	**ML**	**L**	Screening Level Risk Assessment, Cameco 2010b.
		Tailings	Gamma exposure from exposed waste in tailings deltas	Prolonged gamma exposure for wildlife and human	**L**	**ML**	Screening Level Risk Assessment, Cameco 2010b.
			Gamma exposure from tailings in the Minewater Reservoir area	Prolonged gamma exposure for wildlife and human	**L**	**ML**	Screening Level Risk Assessment, Cameco 2010b.
Terrestrial and Aquatic Vegetation	**General**	**Terrestrial Vegetation**	Release of COPC to air	Potential uptake of contaminants in vegetation and impact to VECs	**L**	**L**	Beaverlodge Quantitative Site Model. SENES 2012a. Country Foods Survey. SENES 2012b. Draft.
		Aquatic Vegetation	Leaching of COPC to water	Potential uptake of contaminants in vegetation and impact to VECs	**MH**	**ML**	Beaverlodge Quantitative Site Model. SENES 2012a. Aquatic Macrophyte Sampling Program. CanNorth 2011a. Country Foods Survey. SENES 2012b. Draft.
Risk Communication	**General**	-	Public notification of any site risk	If not done in a timely manner may cause public safety risk	**L**	**L**	Screening Level Risk Assessment, Cameco 2010b.

As can be seen within Table 2.6-1, potential events which were estimated to pose the greatest risk to the environment and public accessing the site include accumulation and release of contaminants from sub-aqueous tailings and sediments and potential uptake of COPC by aquatic vegetation; remedial measures examined within the following section are focused on these features and potential events. It should be noted that with the exception of those potential events noted above, none of these assessed risks were assessed as being higher than a ‘medium-low’ ranking.

2.6.3 Fulton Creek Watershed Assessment of Remedial Activities

Potential remedial measures considered based on identified risks within the Fulton Creek Watershed and/or to meet the standard of good engineering practice:

- Divert fresh water (Fulton Lake outflow) around the BTMA
- Cover sediments within the Fulton Creek Watershed
- Dredge sediments within the Fulton Creek Watershed
- Cover non-aqueous tailings within the Fulton Creek Watershed
- Backfill Minewater Reservoir
- Flood Minewater Reservoir area
- Treat the Greer Lake outflow for Ra-226, Se and U removal

Each of these activities will be discussed in the following sections.

2.6.3.1 Divert fresh water (Fulton Lake outflow) around the BTMA

Two stream diversion scenarios were considered for this area. These stream diversions both involve activities to reroute the freshwater flow from Fulton Lake around the BTMA in order to reduce flow through some of the most heavily impacted areas within the Beaverlodge study area. Conceptual design of these diversions is discussed in SRK (2011). The first diversion scheme involves redirecting flow to Glazebrook Lake by installing a dam at the outlet of Fulton Lake and constructing an unlined channel between Fulton and Glazebrook lakes. Diverted water exiting Glazebrook Lake flows through Greer Lake before entering Fulton Bay of Beaverlodge Lake. The second diversion scheme involves construction of the same dam in Fulton Lake and channel between Fulton and Glazebrook lakes that make up the previous diversion plan and, in addition, there would be a dam constructed at the outlet of Glazebrook Lake along with a channel between Glazebrook and Sells lakes to redirect the outflow of Glazebrook Lake through Sells Lake into Beaverlodge Lake to avoid flow through Greer Lake.

Potential change to environmental conditions based on these stream diversions was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes. Assumptions which were made in order to predict the effects of this stream diversion are:

- It was assumed that these diversions are able to successfully redirect 100% of the flow being addressed (i.e. 100% of Fulton Lake outflow directed to Glazebrook Lake and in the second diversion, 100% of Glazebrook Lake outflow directed to Sells Lake).

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 37% from $1.2x10^6$ kBq/yr to $7.2x10^5$ kBq/yr, a reduction in uranium load of 45% from 165 kg/yr to 91 kg/yr and a reduction in selenium load of 42% from 1.7 kg/yr to 0.97 kg/yr to the downstream environment.

Predicted water quality in the immediate area as well as downstream over the 2010-2150 period is shown in Figures 2.6-2, 2.6-3, 2.6-4, 2.6-5, 2.6-6 and 2.6-7 for Fookes Reservoir, Marie Reservoir, the Meadow Fen, Greer Lake, Fulton Bay and the western region of Beaverlodge Lake, respectively. Results shown in these figures are water quality predictions resulting from the implementation of the second, more extensive diversion. If the first diversion option was selected instead, the predicted water quality within Fookes Reservoir, Marie Reservoir and the Meadow Fen would be the same while levels in Greer Lake would be lower due to dilution with un-impacted water. As can be seen, there is a substantial increase in levels of all three constituents in the water column of the bypassed water bodies. This is primarily due to the fact that there is no longer an influx of fresh water to dilute the load to these regions. There is very little benefit seen downstream in Fulton Bay or the western segment of Beaverlodge Lake as a result of either of these diversion options. Radium-226 is predicted to decrease in Fulton Bay and the western region of Beaverlodge Lake; however, radium-226 is predicted to be below the applicable guideline without remediation in these regions. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors, associated with the complete diversion of Fulton Lake through Sells Lake and into Beaverlodge Lake, are shown in Figures 2.6-8, 2.6-9, 2.6-10, 2.6-11 and 2.6-12 for Fookes Reservoir, the Meadow Fen, Greer Lake, Fulton Bay and the western region of Beaverlodge Lake as compared to the base case, with no remediation. Marie Reservoir is not shown as receptors were not assessed at this location. As can be seen, implementation of this stream flow diversion is predicted to increase risk to scaup within Fookes Reservoir and have no effect on any exceedances predicted in the other examined areas within the Fulton Creek Watershed and Beaverlodge Lake.

Costs of these two stream diversions were estimated by SRK (2011) and further discussed in SENES & SRK (2012) to be approximately $13.1 and $23.8 million CAD for the first and second diversion schemes, respectively. These costs include the net present value (NPV) of a $10,000 CAD per year maintenance cost.

Figure 2.6-2 Fookes Reservoir Water Quality Predictions (Divert Fulton Lake Outflow)

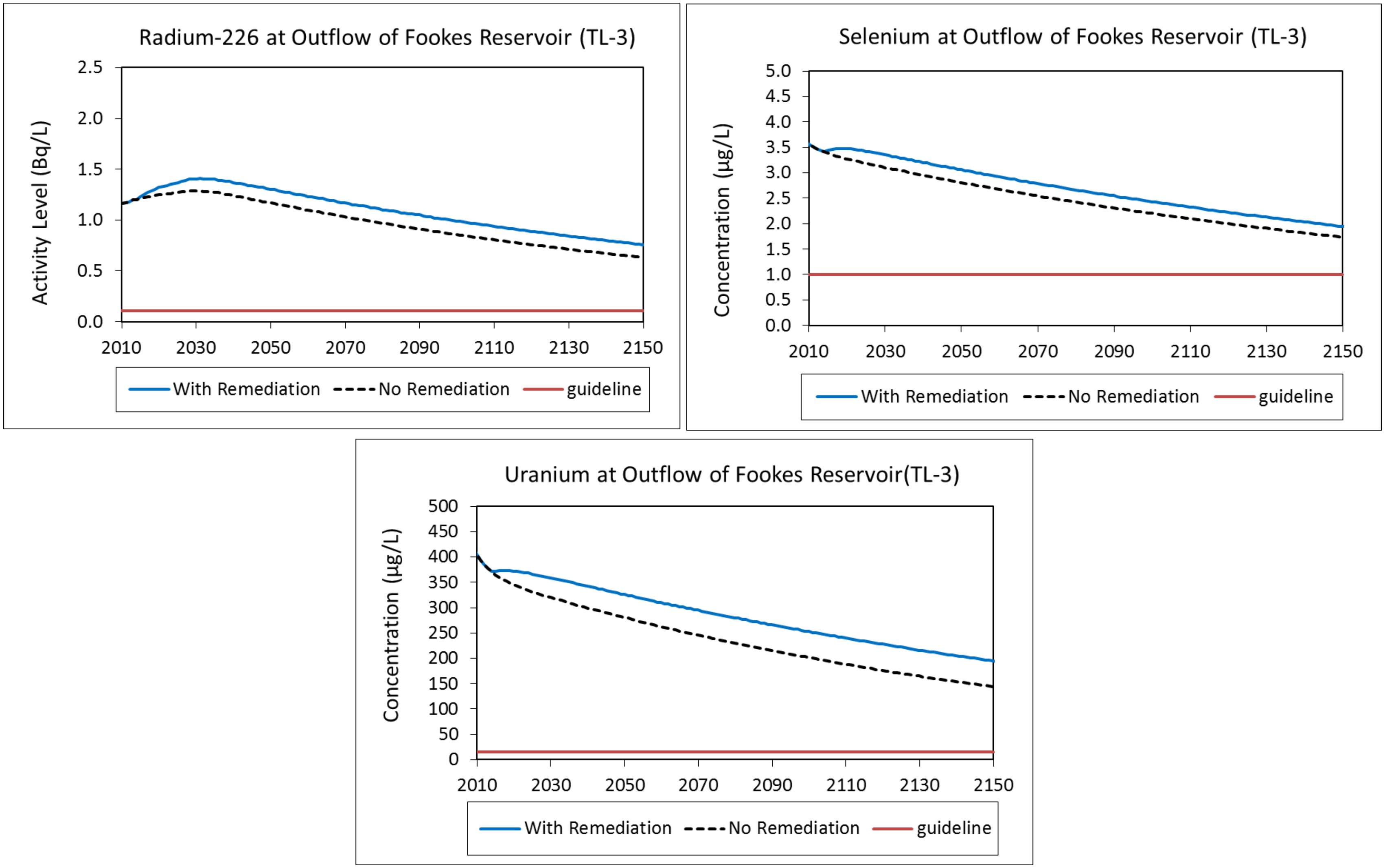
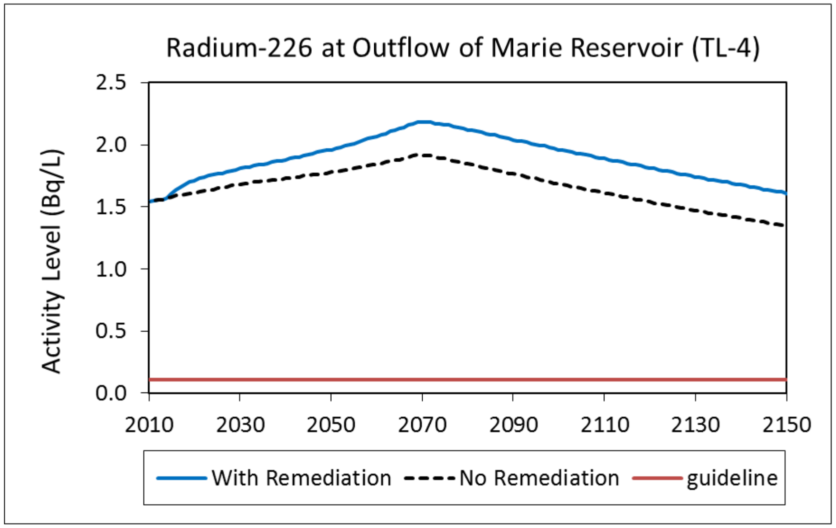
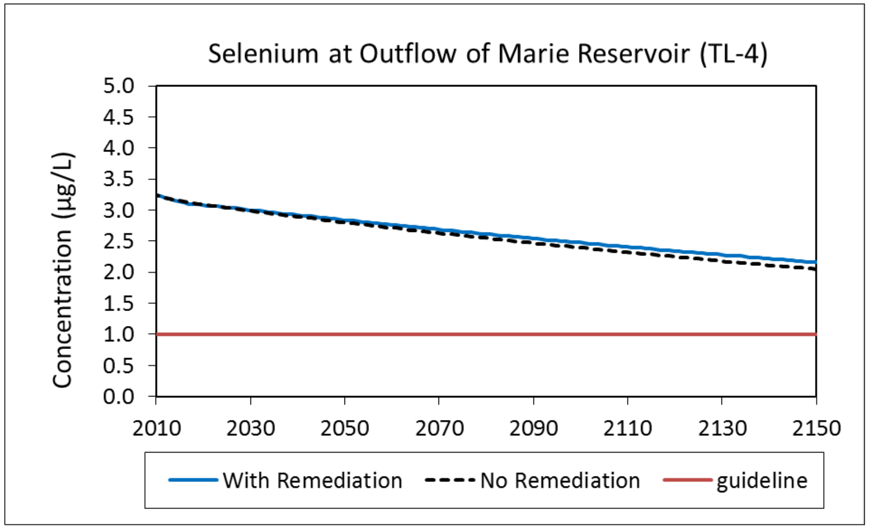


Figure 2.6-3 Marie Reservoir Water Quality Predictions (Divert Fulton Lake Outflow)





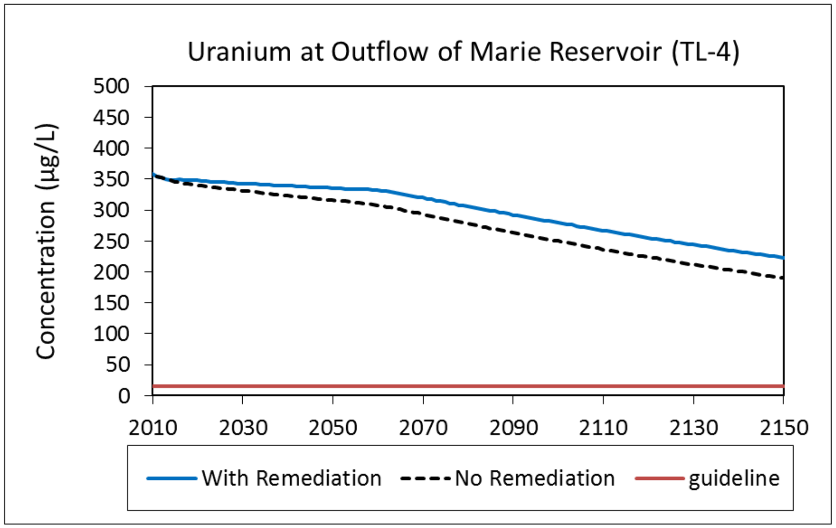


Figure 2.6-4 The Meadow Fen Water Quality Predictions (Divert Fulton Lake Outflow)

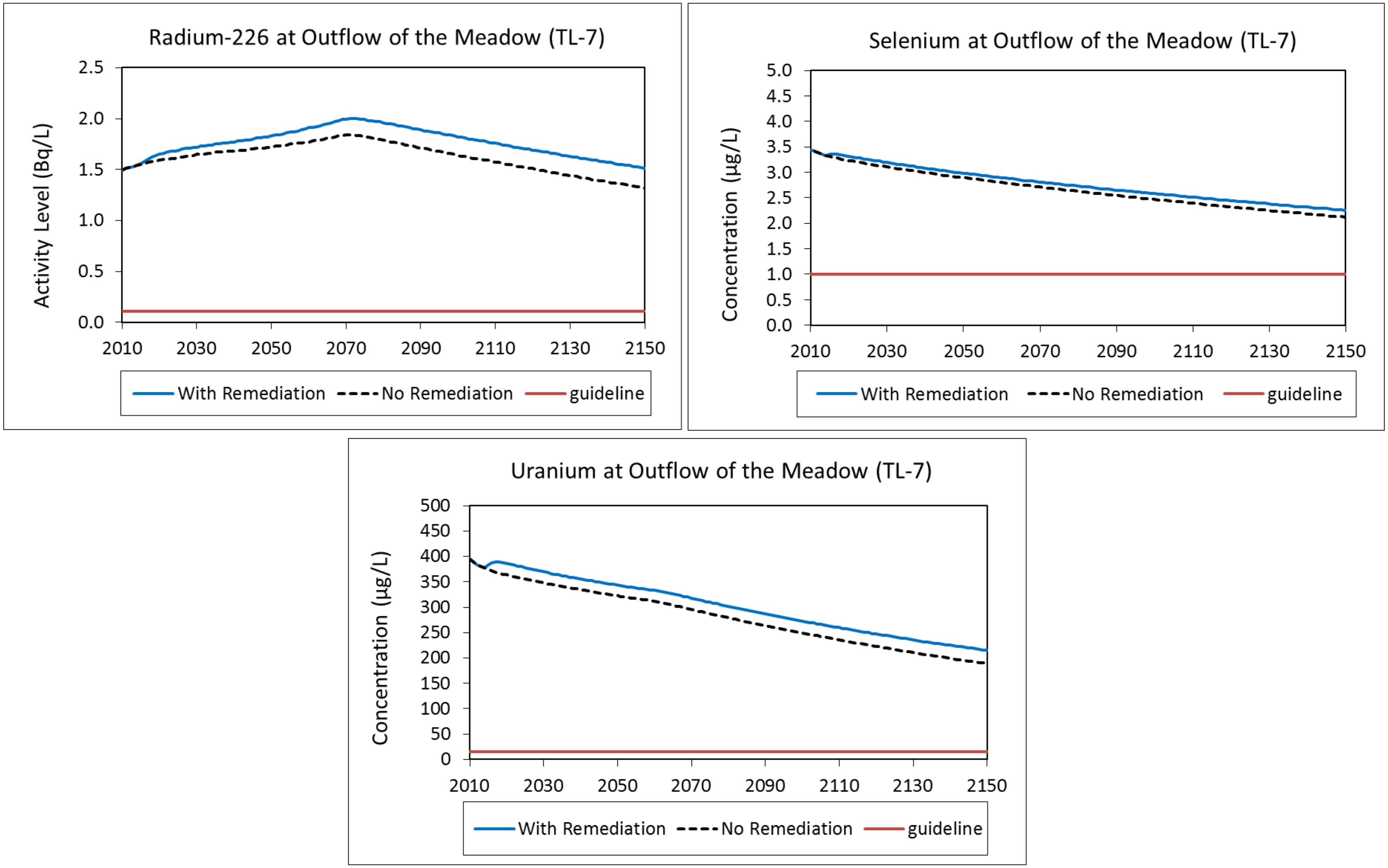


Figure 2.6-5 Greer Lake Water Quality Predictions (Divert Fulton Lake Outflow)

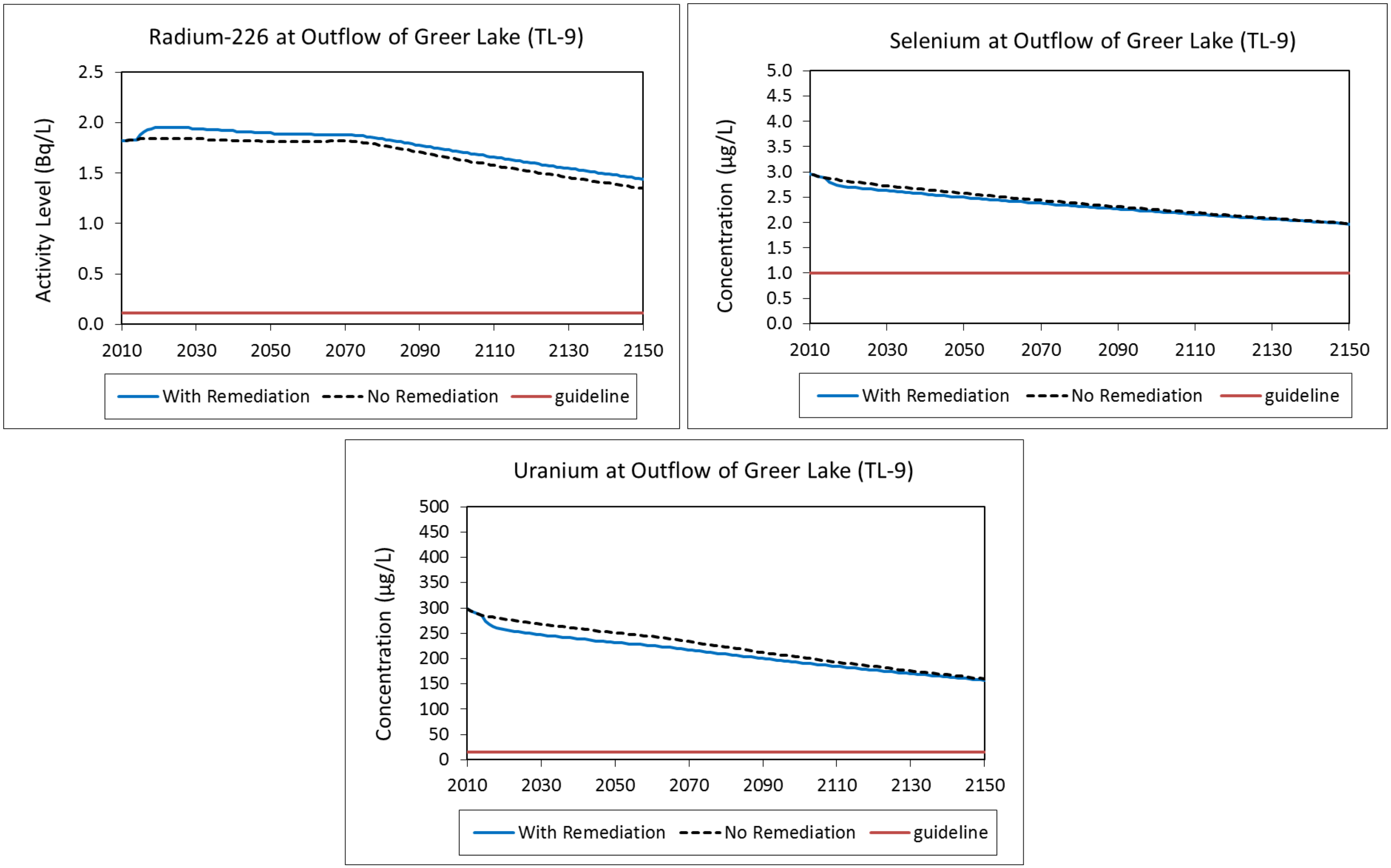


Figure 2.6-6 Fulton Bay, Beaverlodge Lake Water Quality Predictions (Divert Fulton Lake Outflow)

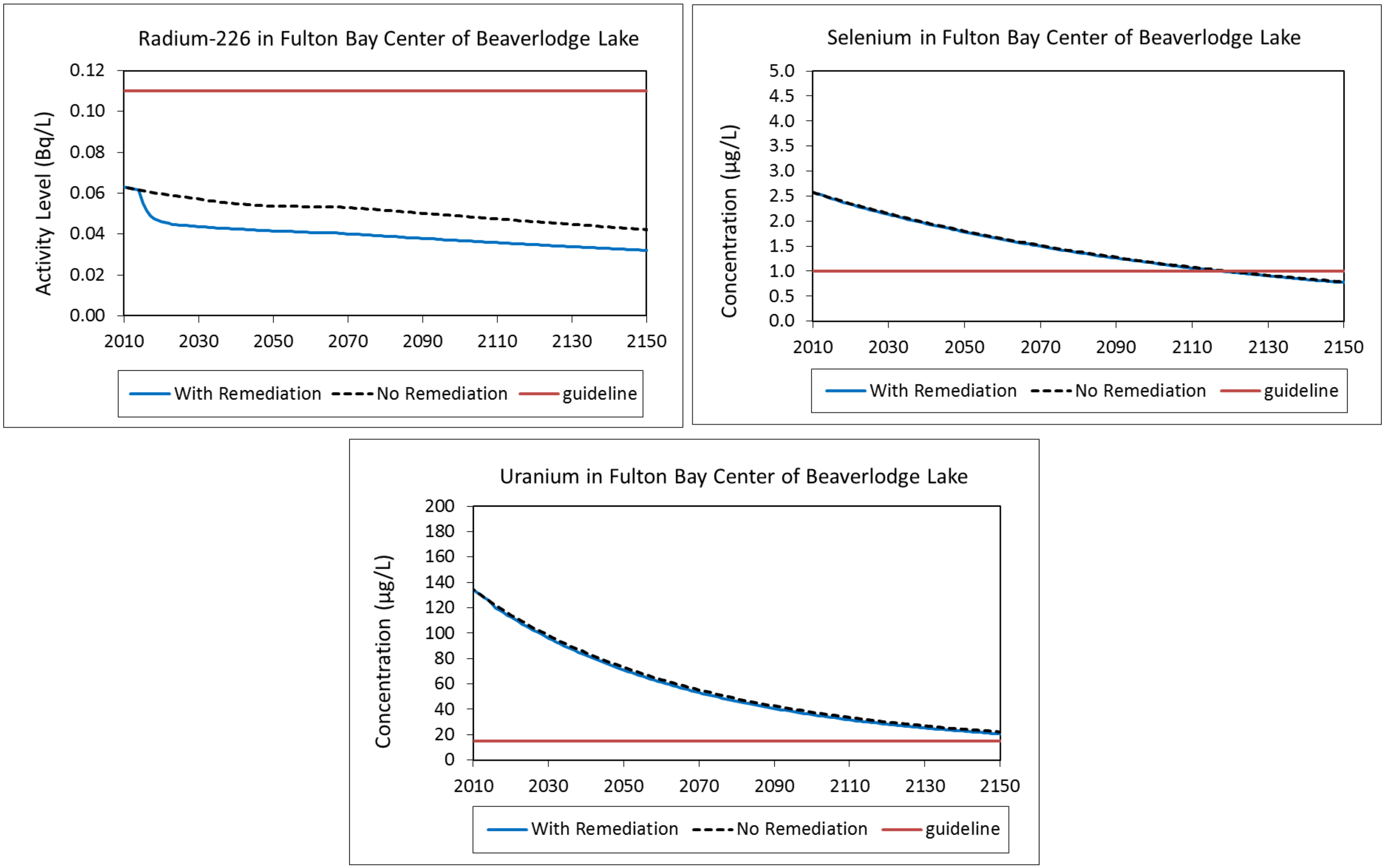


Figure 2.6-7 Western Segment, Beaverlodge Lake Water Quality Predictions (Divert Fulton Lake Outflow)

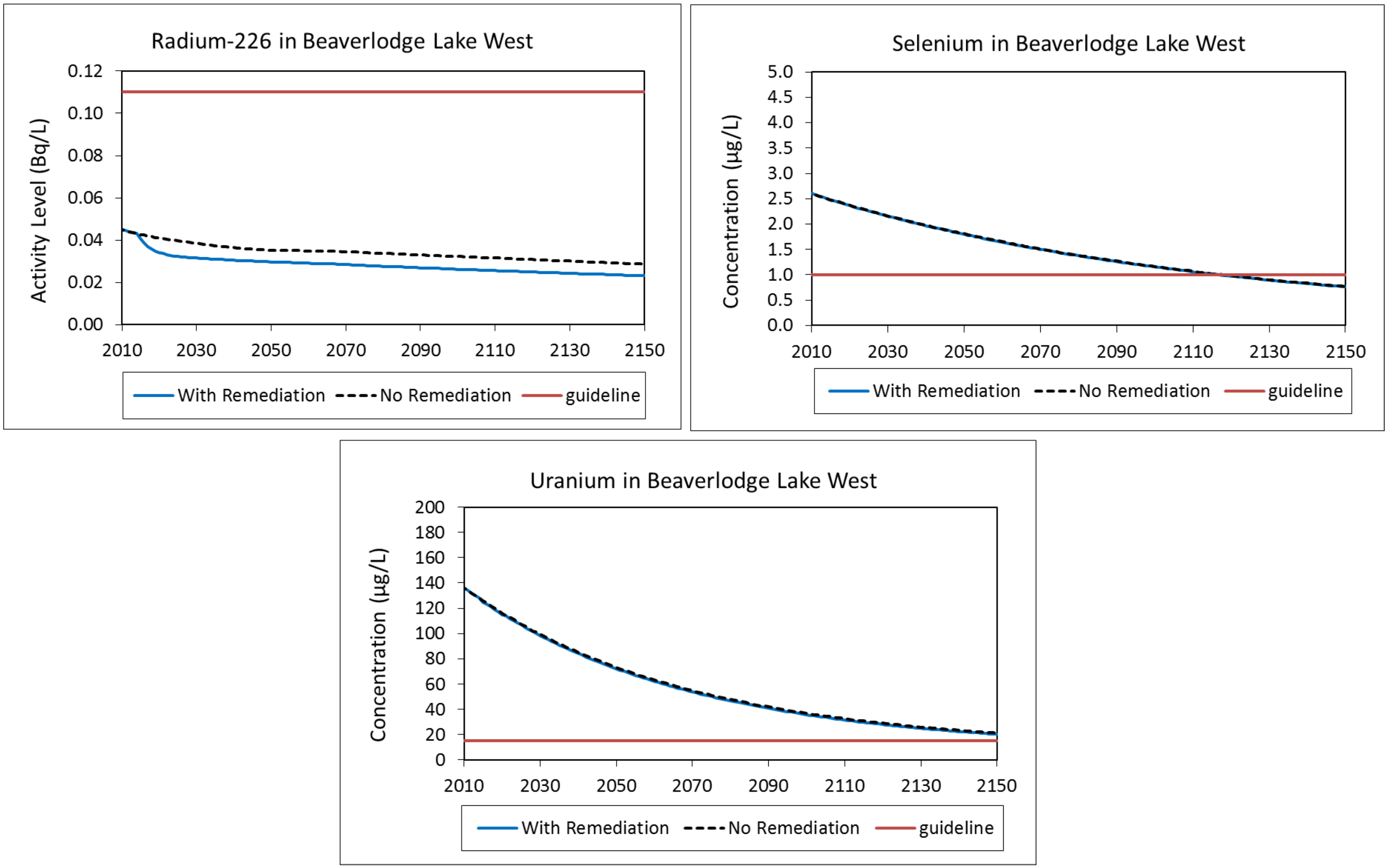


Figure 2.6-8 Summary of Outcomes in Fookes Reservoir (Divert Fulton Lake Outflow)

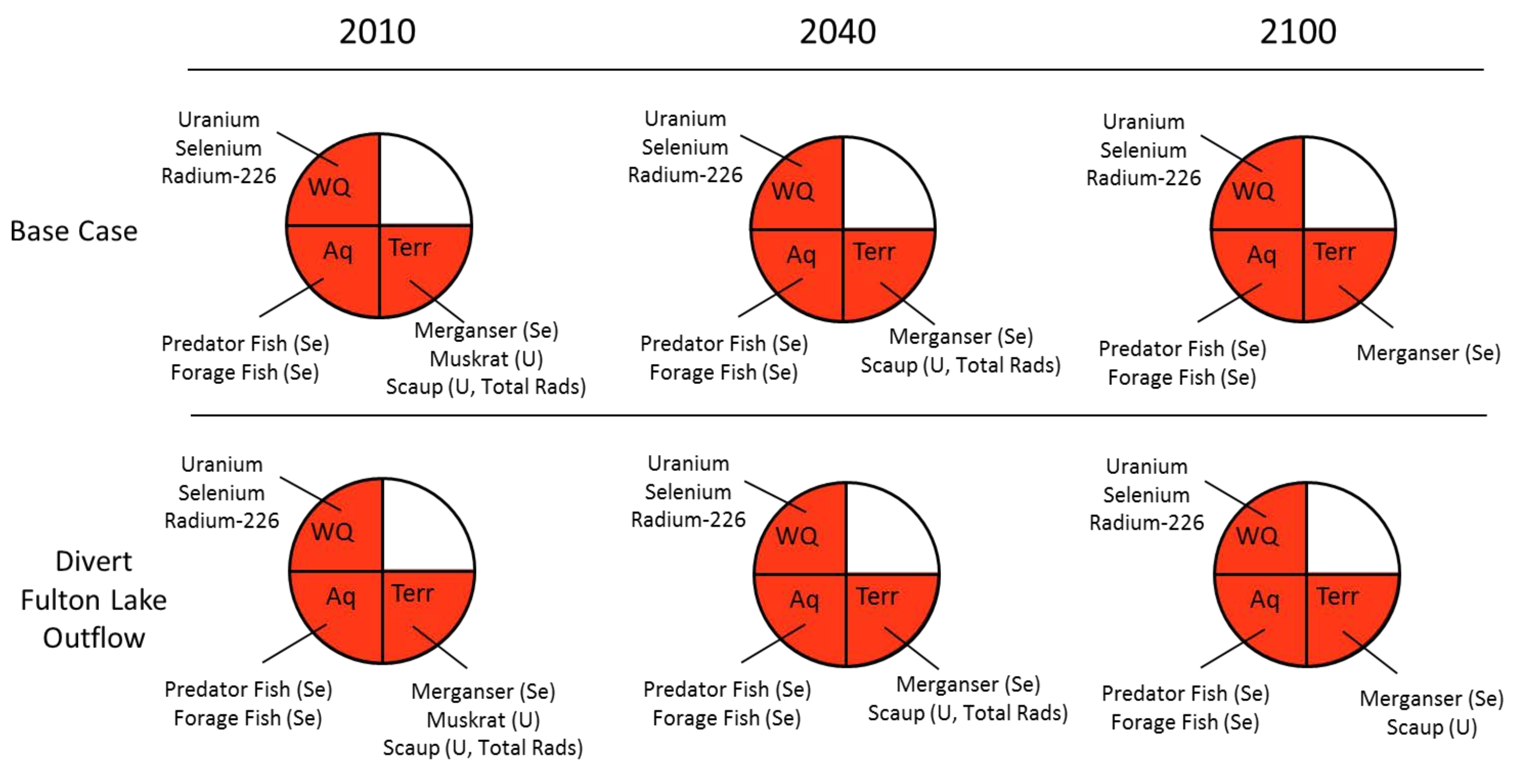


Figure 2.6-9 Summary of Outcomes in the Meadow Fen (Divert Fulton Lake Outflow)

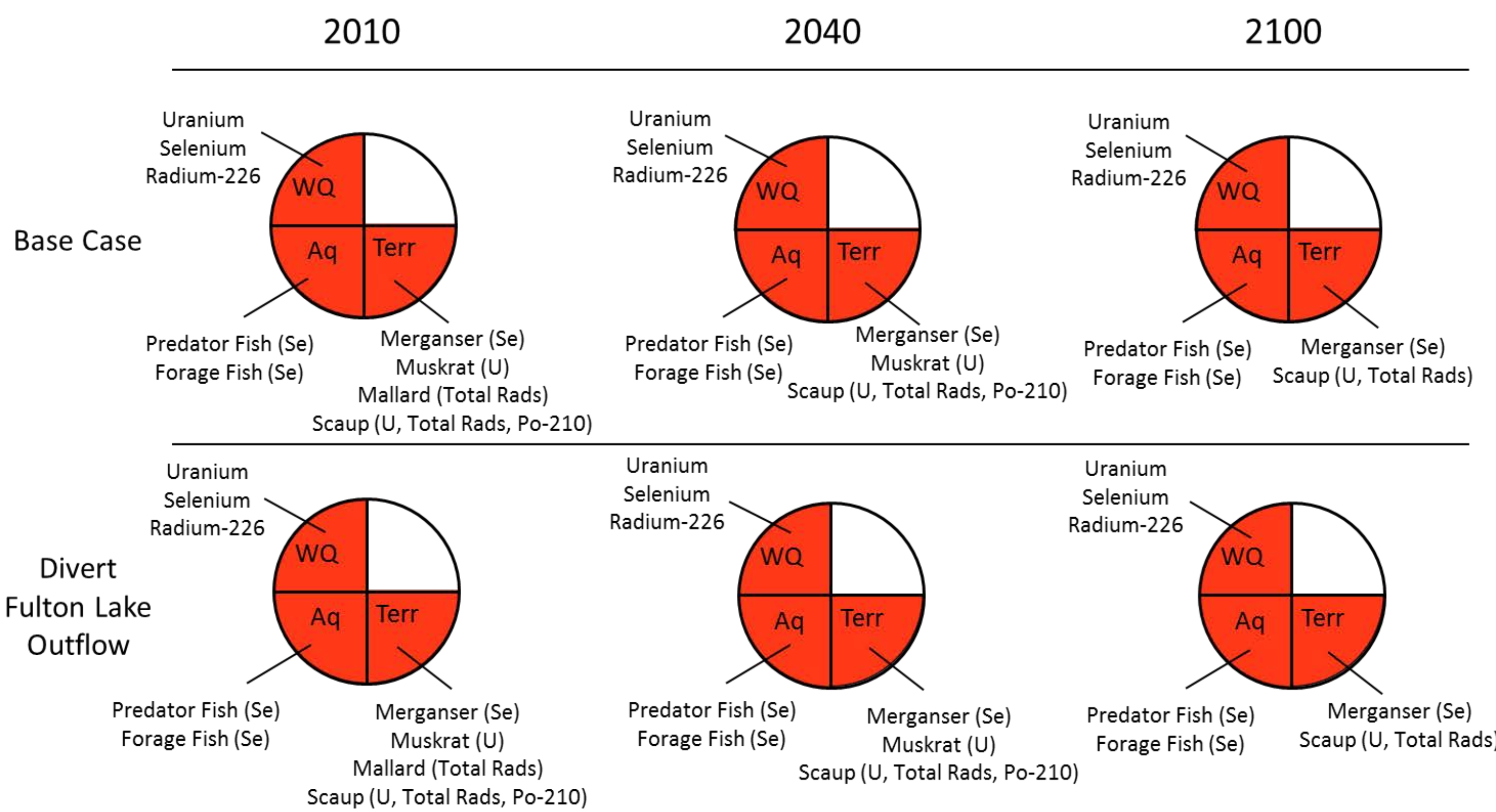


Figure 2.6-10 Summary of Outcomes in Greer Lake (Divert Fulton Lake Outflow)

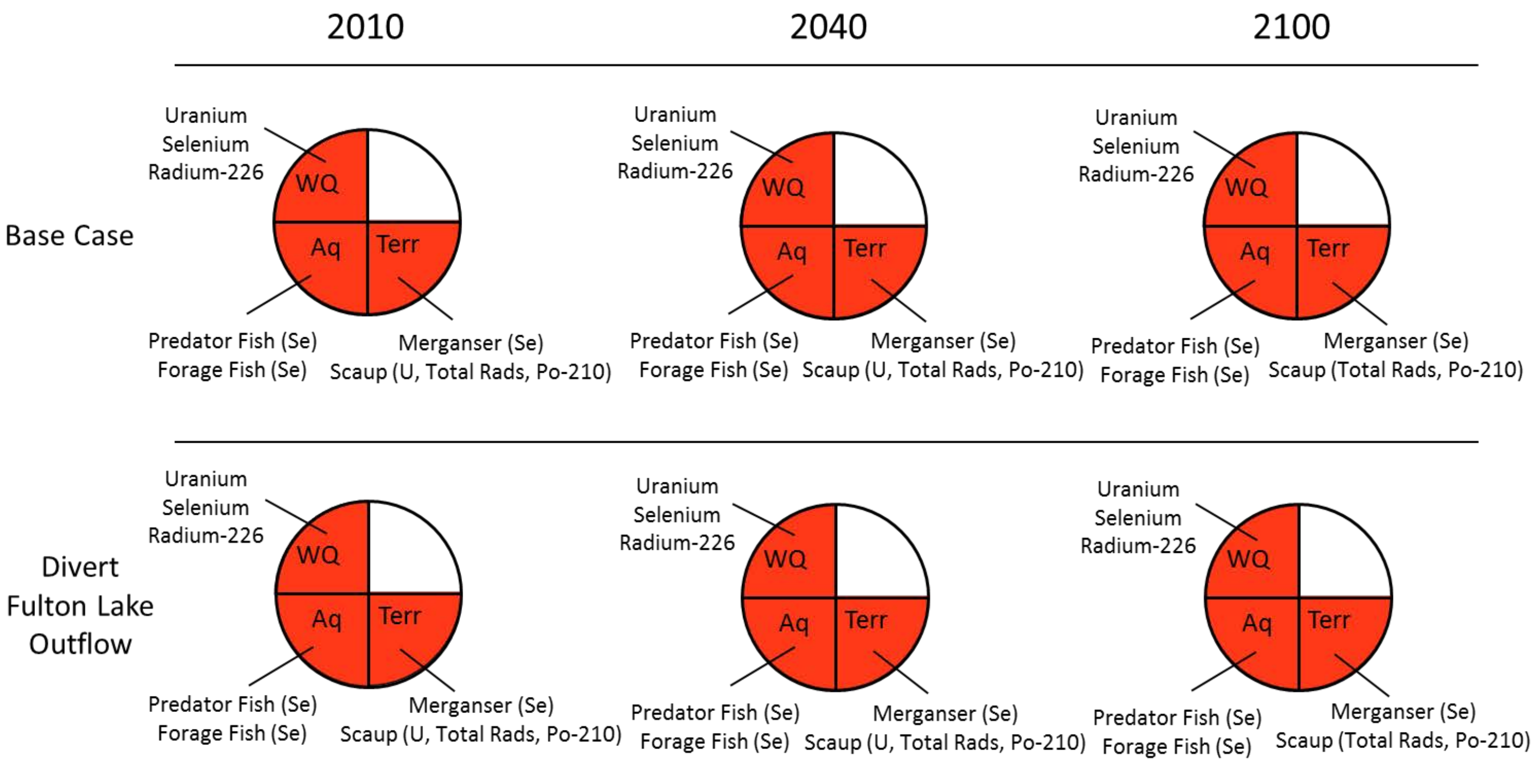


Figure 2.6-11 Summary of Outcomes in Fulton Bay, Beaverlodge Lake (Divert Fulton Lake Outflow)

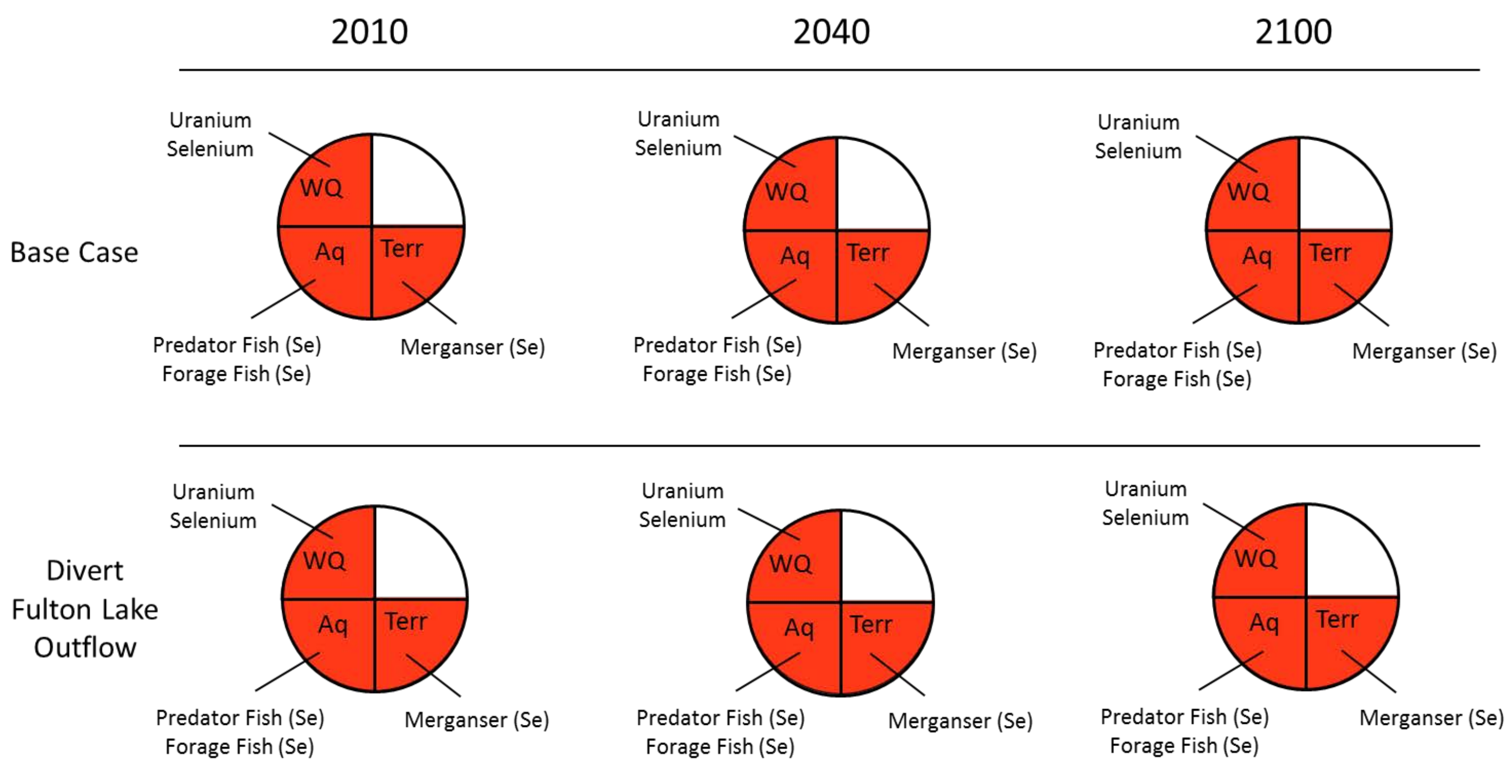
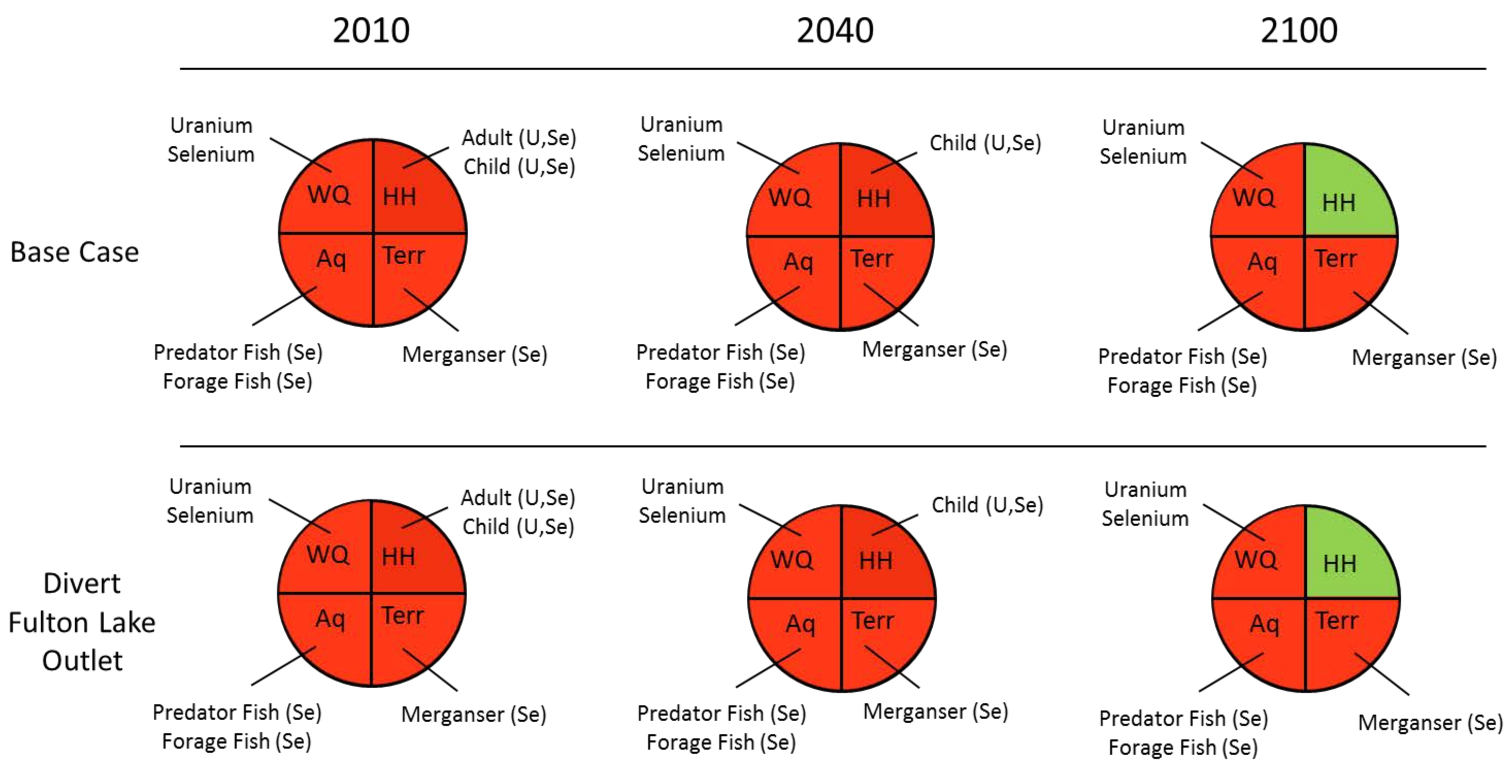


Figure 2.6-12 Summary of Outcomes in the Western Segment of Beaverlodge Lake (Divert Fulton Lake Outflow)



2.6.3.2 Cover Sediments within the Fulton Creek Watershed

This activity involves applying a sand cover to sediments in Fookes Reservoir, Marie Reservoir, Minewater Reservoir, Unnamed Reservoir, the Meadow Fen and Greer Lake to act as a barrier to reduce the flux of contaminants from the sediment and also reduce contact of biota with contaminants present in the sediment. Covering of sediments would be achieved by pumping a sand slurry onto the surface of the sediments by barge. It is assumed that borrow materials for this activity would be locally sourced from previously identified areas (SENES & SRK 2012).

Potential change to environmental conditions based on covering sediments in the water bodies within the Fulton Creek Watershed was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of covering sediments in the Fulton Creek Watershed are:

- Cover material assumed to be a typical sandy fill (porosity of 0.4 and tortuosity of 3)
- 10 cm of cover material placed, mixes with the top 5 cm of pre-existing sediments
- Able to effectively cover 95% of each lakebed
- Sand cover on sediments in Minewater and Unnamed reservoirs reduces total load from Minewater and Unnamed areas by 50%
- It is expected that spreading sand on the surface of the sediments will result in a degree of sediment disturbance and a release of contaminants to the overlying water during the placement process. This may require treatment of the water in the overlying water body prior to its discharge downstream. This has not been included in the estimated cost.

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 56% from 1.2×10^6 kBq/yr to 5.1×10^5 kBq/yr, a reduction in uranium load of 36% from 165 kg/yr to 105 kg/yr and a reduction in selenium load of 48% from 1.7 kg/yr to 0.87 kg/yr to the downstream environment.

Predicted water quality over the 2010-2150 period is shown in Figures 2.6-13, 2.6-14, 2.6-15, 2.6-16 and 2.6-17 for Fookes Reservoir, Marie Reservoir, the Meadow Fen, Greer Lake and Fulton Bay, respectively. Moderate improvements in water quality are seen in all waterbodies with covered sediments. There is however no reduction to selenium or uranium downstream in Fulton Bay of Beaverlodge Lake. The radium-226 level is predicted to be reduced in Fulton Bay; however, the radium-226 level in this area is predicted to be below the applicable guideline even without additional remedial activities. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.6-18, 2.6-19, 2.6-20 and 2.6-21 for Fookes Reservoir, the Meadow Fen, Greer Lake and Fulton Bay as compared to the base case, with no remediation. Marie Reservoir is not shown as receptors were not assessed at this location. As can be seen, implementation of this activity reduces the predicted risk to terrestrial receptors assessed at Fookes Reservoir, the Meadow Fen and Greer Lake; however, exceedances remain unchanged at these locations for water quality and aquatic receptors. Looking downstream, there is no change to exceedances predicted for any receptors considered at Fulton Bay of Beaverlodge Lake.

Costs of applying this sand cover to sediments in the Fulton Creek Watershed were estimated by SENES & SRK (2012) to be approximately $27 million CAD.

Figure 2.6-13 Fookes Reservoir Water Quality Predictions (Cover Fulton Creek Sediments)

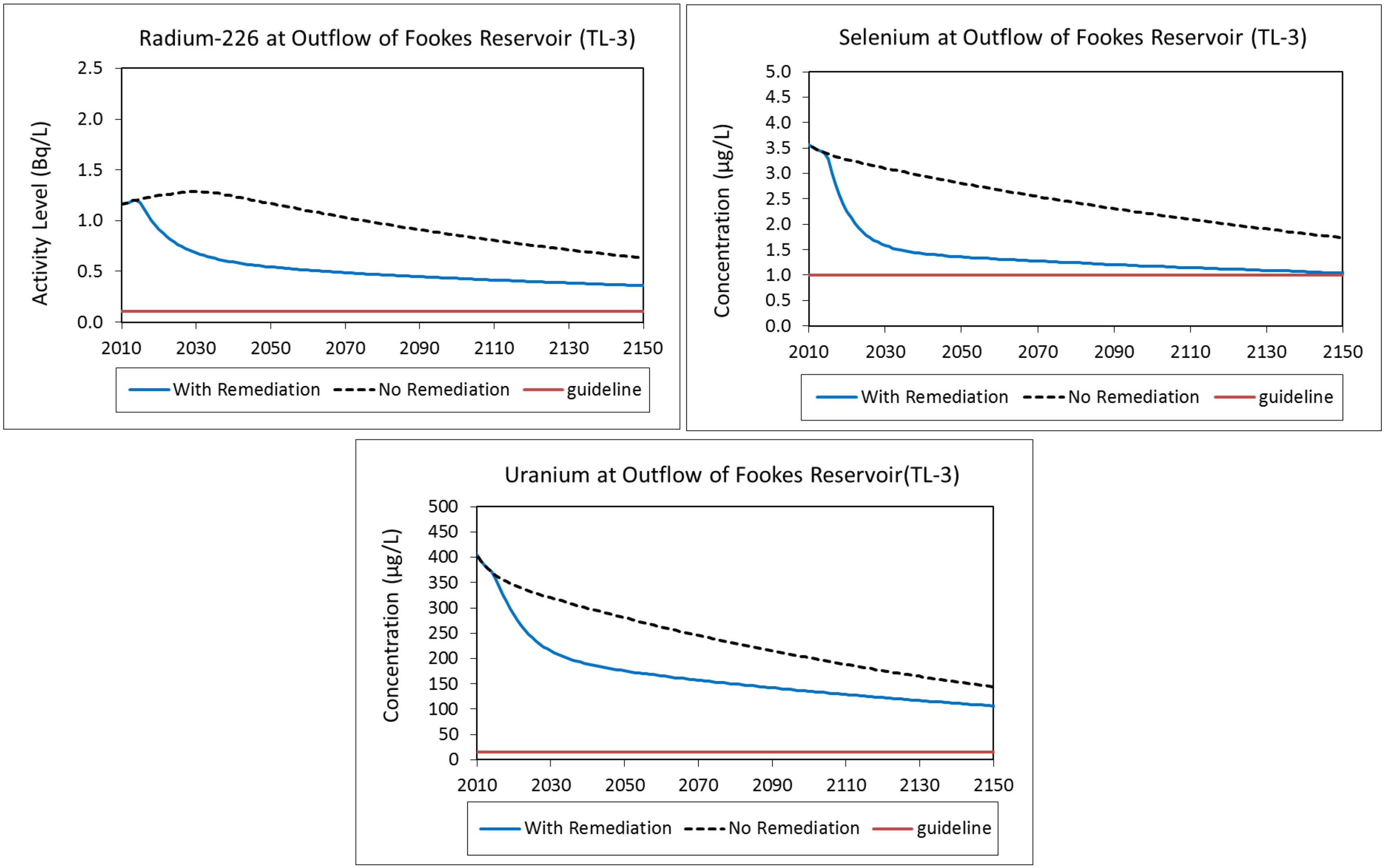


Figure 2.6-14 Marie Reservoir Water Quality Predictions (Cover Fulton Creek Sediments)

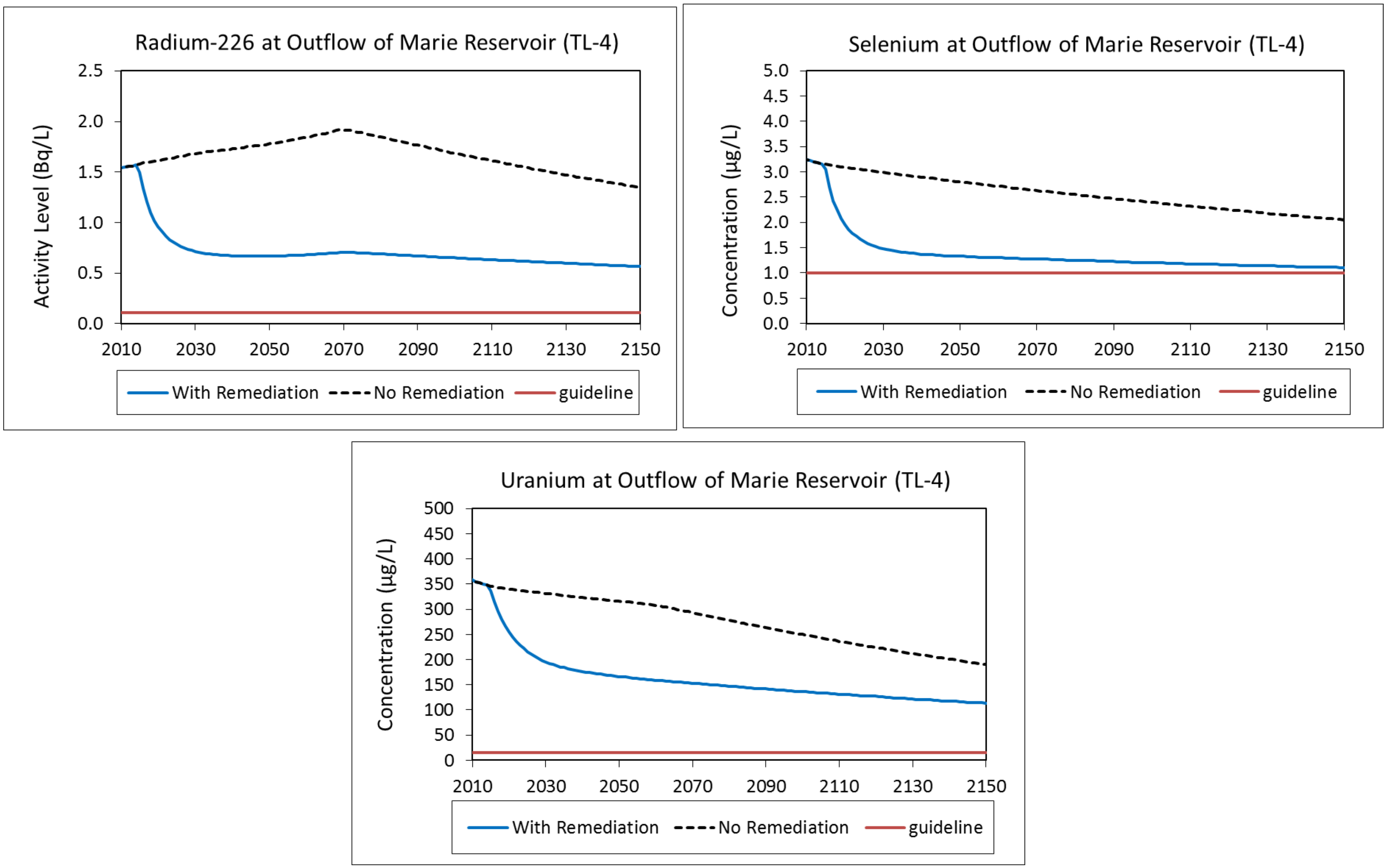


Figure 2.6-15 The Meadow Fen Water Quality Predictions (Cover Fulton Creek Sediments)

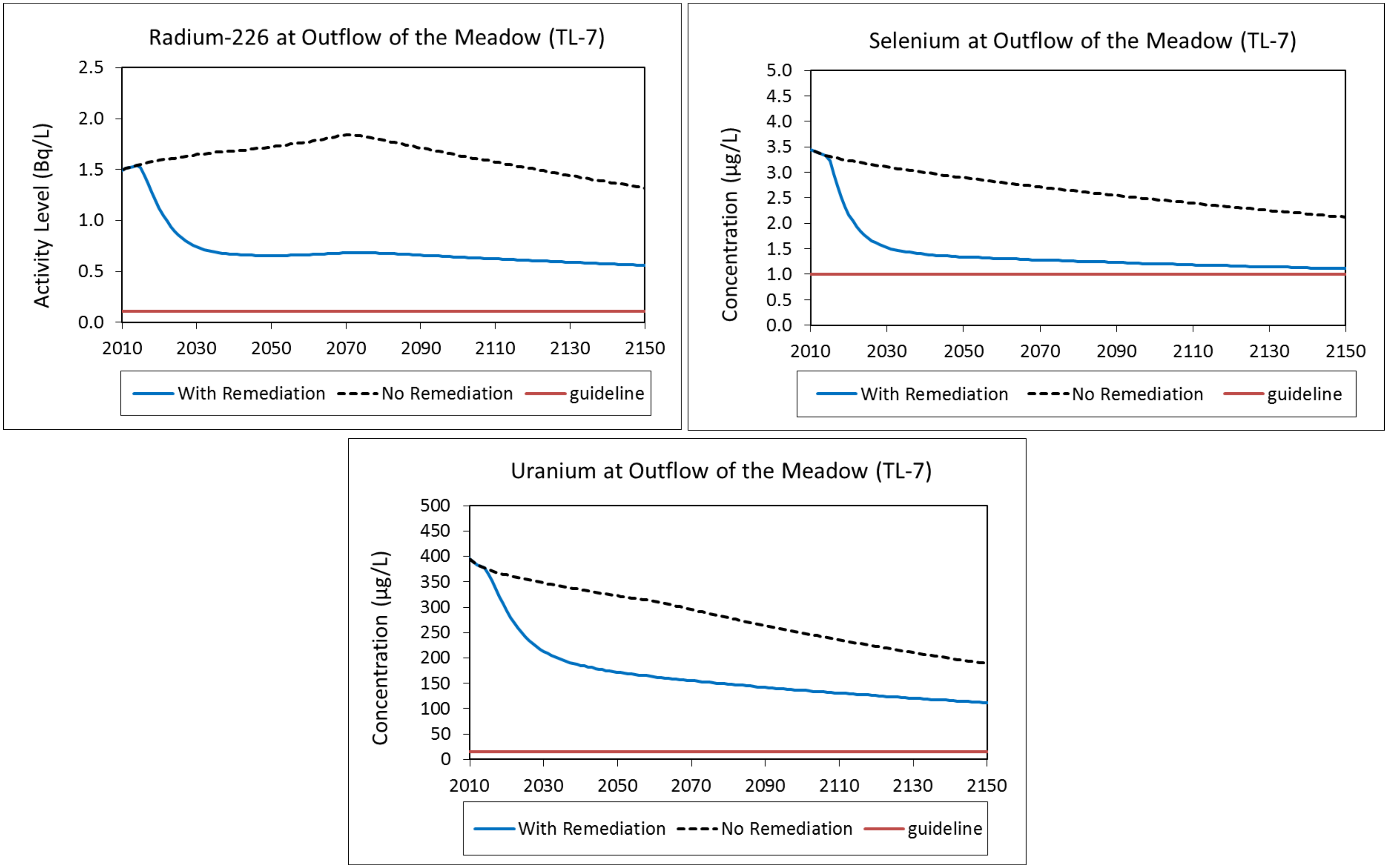


Figure 2.6-16 Greer Lake Water Quality Predictions (Cover Fulton Creek Sediments)

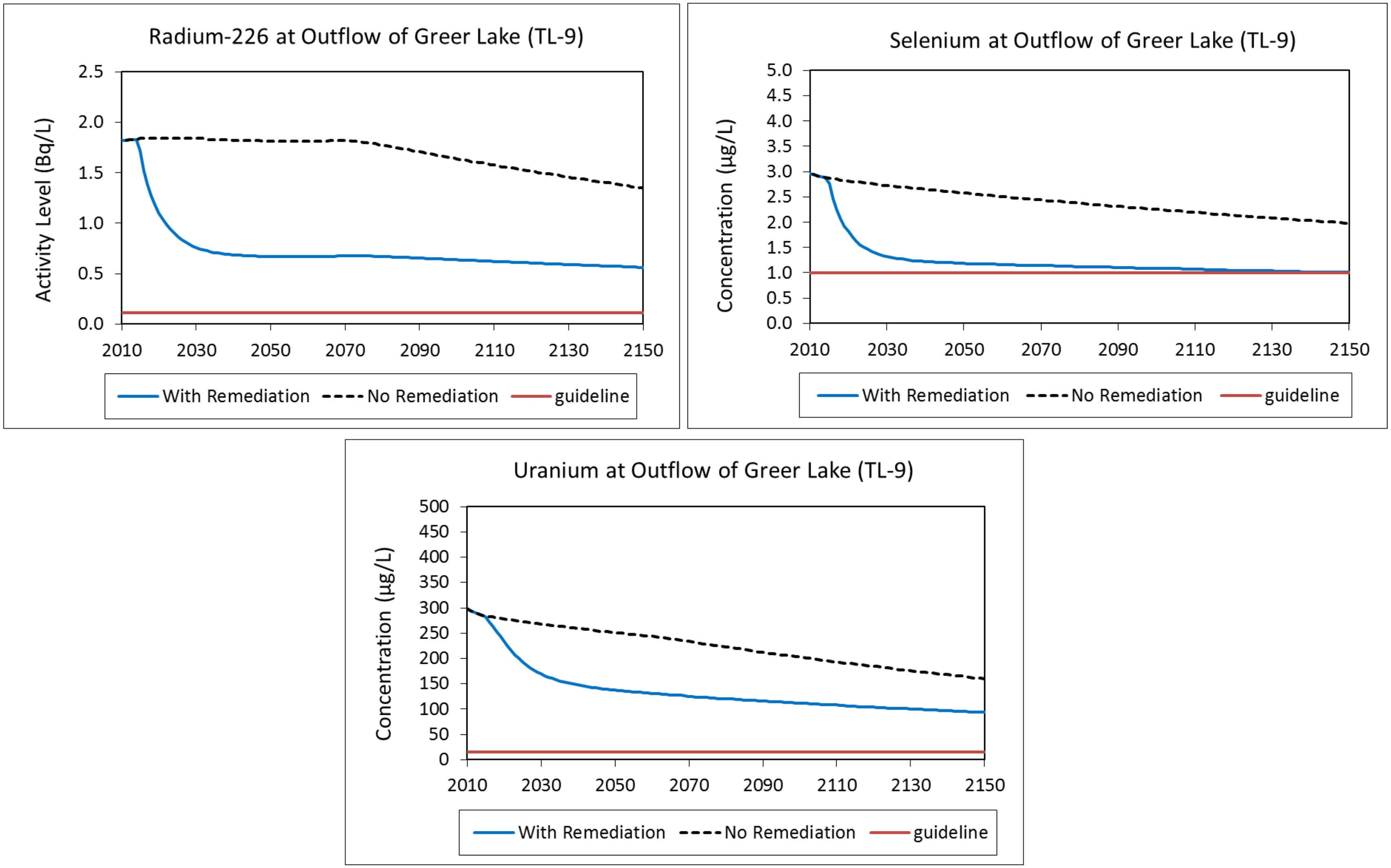


Figure 2.6-17 Fulton Bay, Beaverlodge Lake Water Quality Predictions (Cover Fulton Creek Sediments)

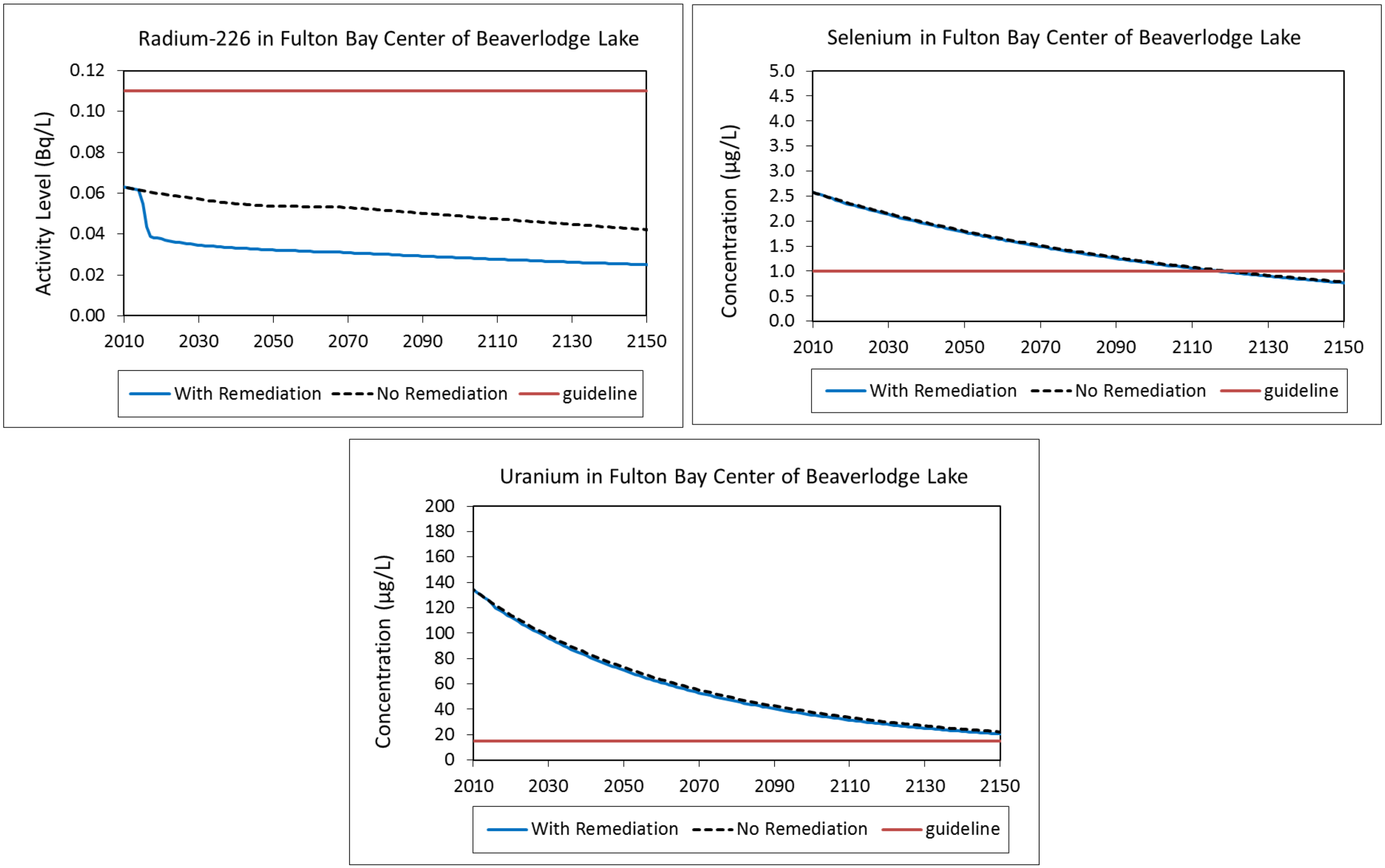


Figure 2.6-18 Summary of Outcomes in Fookes Reservoir (Cover Fulton Creek Sediments)

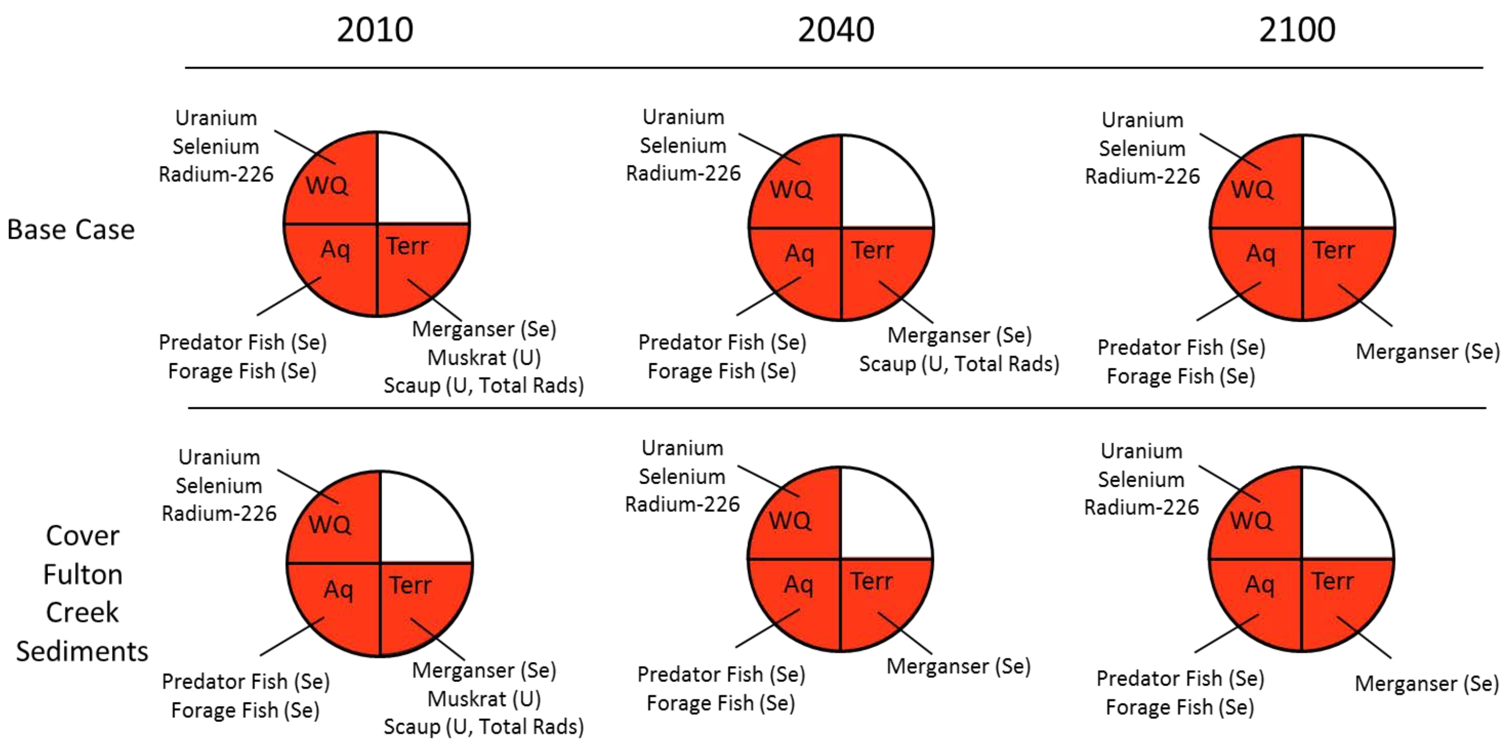


Figure 2.6-19 Summary of Outcomes in the Meadow Fen (Cover Fulton Creek Sediments)

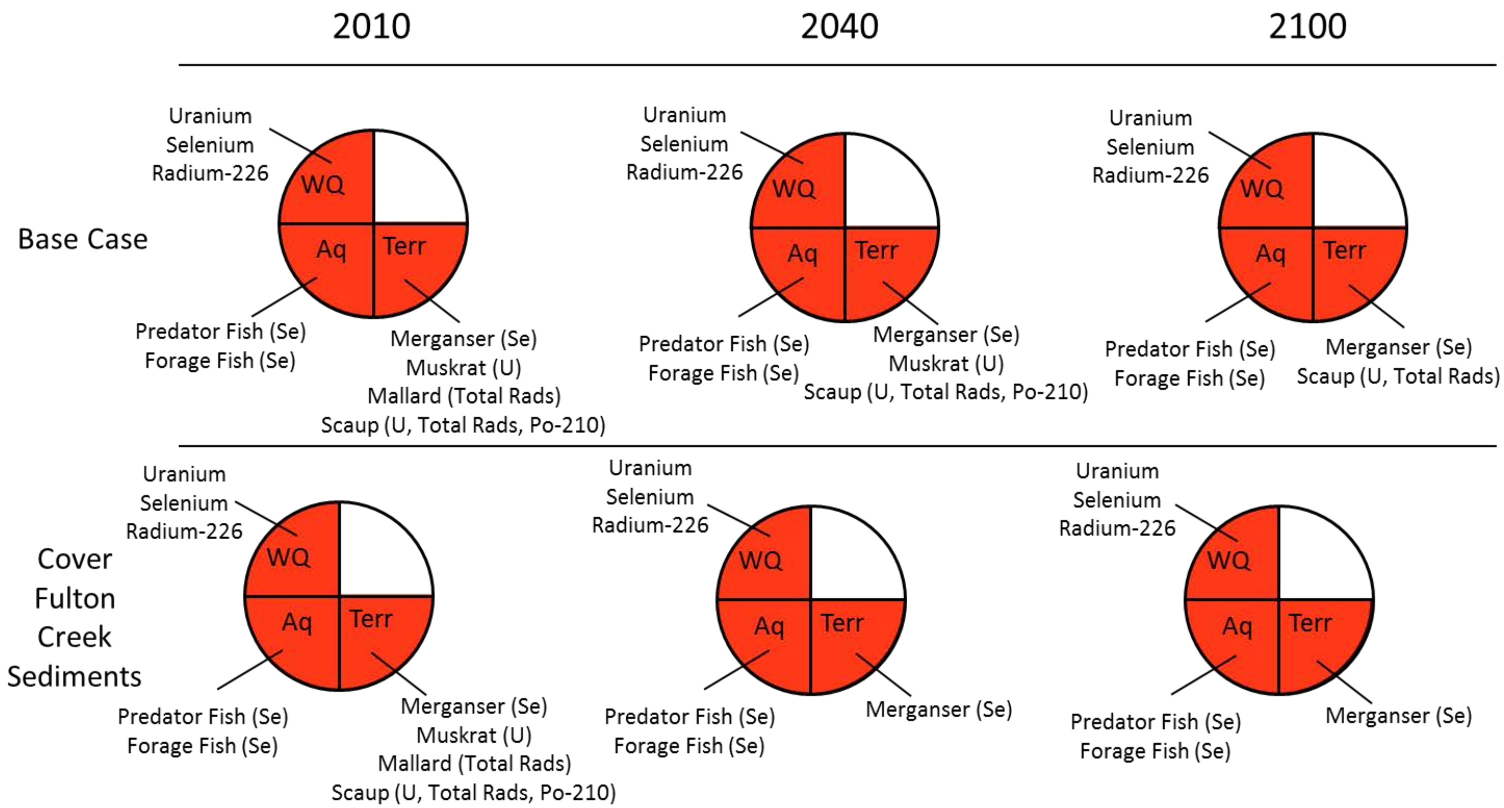


Figure 2.6-20 Summary of Outcomes in Greer Lake (Cover Fulton Creek Sediments)

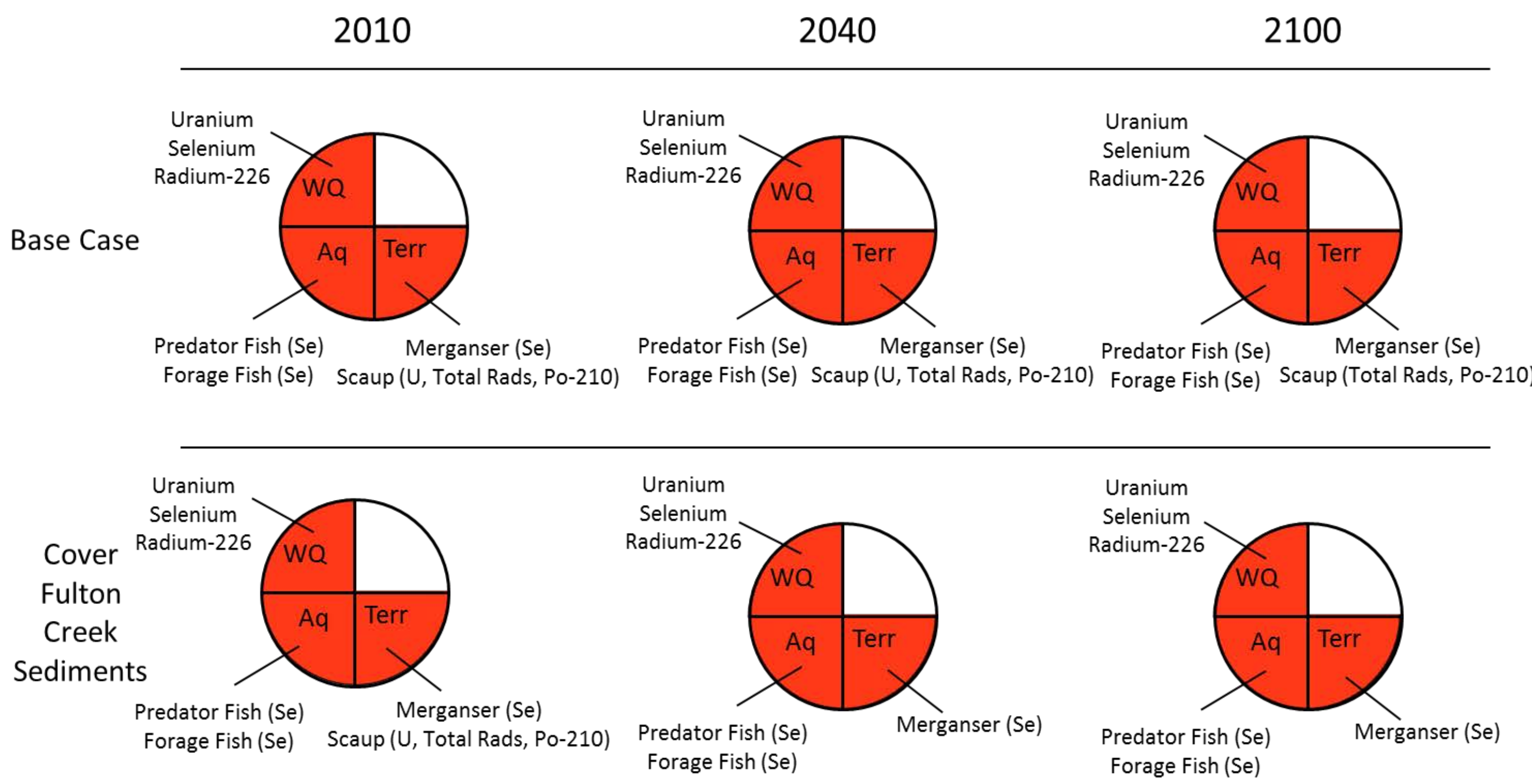
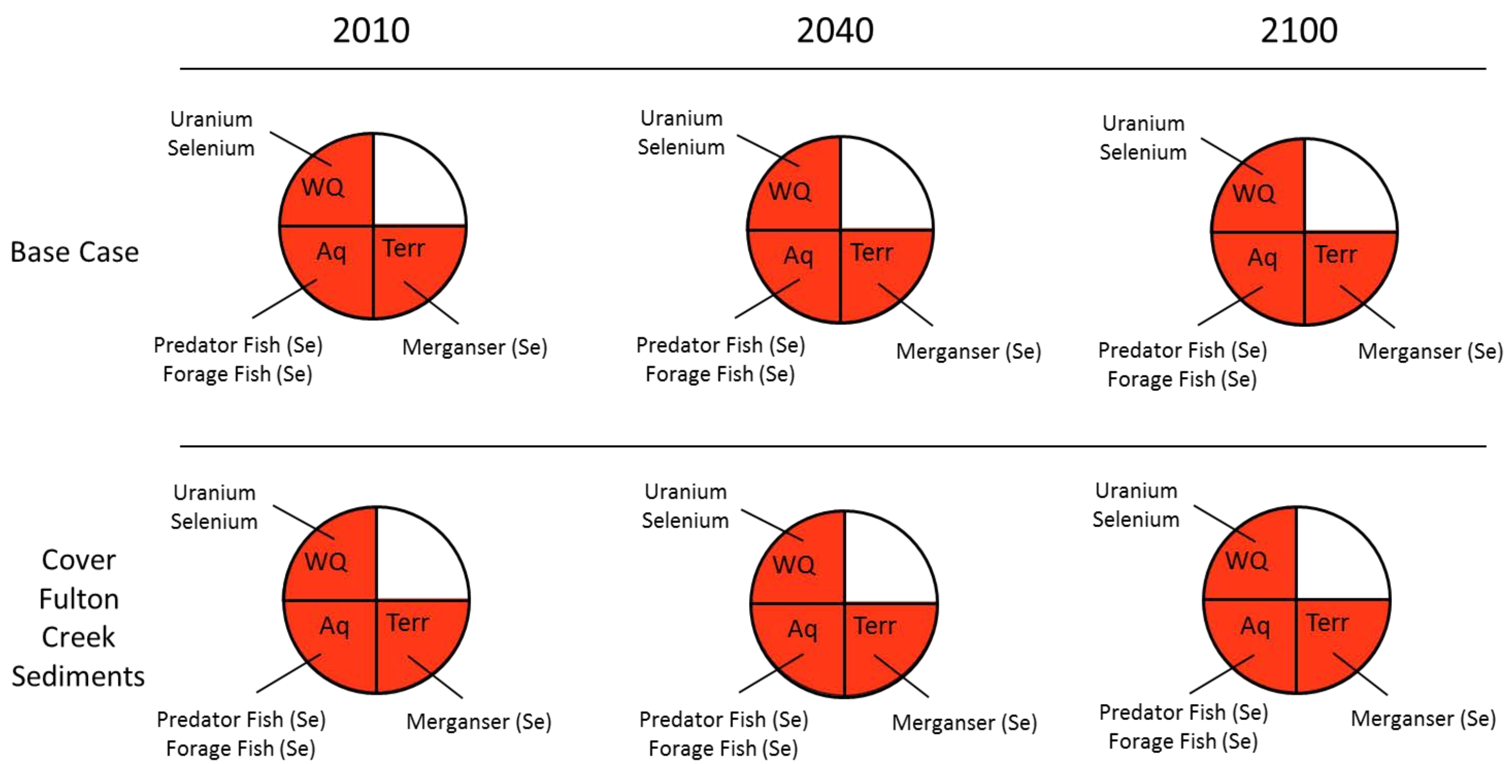


Figure 2.6-21 Summary of Outcomes in Fulton Bay, Beaverlodge Lake (Cover Fulton Creek Sediments)



2.6.3.3 Dredge Sediments within the Fulton Creek Watershed

This activity involves removal of sediments from the main waterbodies in the Fulton Creek Watershed (Marie Reservoir, Minewater Reservoir, Unnamed Reservoir, the Meadow Fen and Greer Lake) and storage of these impacted sediments in Fookes Reservoir. The purpose of this activity would be to remove impacted sediments to a single location where they can be more easily managed. Removal of sediments would be done using a combination of dredging and mechanical (dragline) removal. It should be noted that these methods were already applied to Minewater Reservoir and the Meadow Fen during decommissioning with limited success. Implementation of this activity would include installation of coffer dams throughout the system to contain suspended sediments in both the water body being dredged and also Fookes Reservoir.

Potential change to environmental conditions based on dredging sediments in the water bodies within the Fulton Creek Watershed was not assessed using the Beaverlodge QSM (SENES 2012a) as the technical uncertainties of implementing this remedial measure are high. It should be noted that the success of this measure is uncertain for a number of reasons including; due to the light flocculent nature of many of the sediments in these water bodies, capture will be extremely difficult; and, the ability to effectively contain the removed sediments in Fookes Reservoir is not proven which may result in re-contamination of the downstream waterbodies over time. It is expected that these measures would likely have a very negative short term impact on the ecological systems present in all involved waterbodies.

It should be noted that in order to manage the consolidated sediments within Fookes Reservoir, long term operation and maintenance of a water treatment plant and/or dam structures would likely be required.

Costs of these dredging and relocating operations were estimated by SENES & SRK (2012) to be approximately $34.5 million CAD. Additional costs of managing sediments within Fookes Reservoir, such as ongoing water treatment and/or placement of a sediment cover, would be additional.

2.6.3.4 Cover of Non-aqueous Tailings within the Fulton Creek Watershed

This activity involves applying a sand cover to tailings located on land within the Fulton Creek Watershed. As discussed in SENES & SRK (2012) the placement of sand on top of exposed tailings is expected to reduce surface gamma levels but would have no material effect on precipitation infiltration as the tailings have lower permeability than the cover materials. For this reason cover of tailings with sand was not assessed using the Beaverlodge QSM (SENES 2012a). Covering tailings in these areas with a more impermeable cover, such as HDPE, is also not expected to significantly reduce contaminant loads due to the low permeability of the tailings and there is no benefit to be gained over a sand cover to reduce gamma levels. For this reason, placement of a synthetic liner was not evaluated for covering exposed tailings within the Fulton Creek Watershed.

The non-aqueous tailings in the Fulton Creek Watershed are located in the tailings deltas on the banks of Fookes and Marie reservoirs, along the former tailings lines as well as in the area around Minewater Reservoir. Both of the tailings deltas were covered with a layer of waste rock post decommissioning and then, in response to the reoccurrence of tailings boils, tailings in the Fookes Reservoir delta were also covered with a layer of sand. The tailings around Minewater Reservoir were cleaned up and placed down the Fay shaft during decommissioning. What remains at this site are small areas of tailings which were not removed during the extensive clean-up efforts. While elevated levels of gamma radiation are not observed around the Fookes and Marie deltas, gamma levels as high as 13 µSv/hr have been observed around Minewater Reservoir. This remedial measure deals with application of sand cover to easily accessible tailings within the elevated gamma areas around Minewater Reservoir and the former tailings lines as well as tailings in the Marie Reservoir delta to decrease the likelihood of tailings boils in the future. It is expected that cover placement on tailings in the Minewater Reservoir area would be able to reduce exposure to less than 2.5 µSv/hr.

Costs of applying a sand cover to easily accessible non-aqueous tailings in the Fulton Creek Watershed (primarily tailings located in the Marie Reservoir delta, along the former tailings lines and around Minewater Reservoir) were estimated to be approximately $1 million CAD based on past experience with covering tailings within the Fookes Reservoir delta.

2.6.3.5 Backfill Minewater Reservoir

This activity involves backfilling Minewater Reservoir with clean material. This activity would not only reduce the release of constituents from sediments, subaqueous mine slimes and tailings in the sediment bed but would also eliminate a large portion of the reservoir and therefore reduce wildlife access to the water and sediments.

Potential effects of backfilling Minewater Reservoir were assessed using the Beaverlodge QSM (SENES 2012a) assuming these activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- Infilling Minewater Reservoir reduces total load from the Minewater Reservoir and Unnamed Reservoir areas by approximately 50%

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 0.1% a reduction in uranium load of 3% and a reduction in selenium load of 1% to the downstream environment.

It should be noted that a 50% reduction is likely quite optimistic as the load from the Minewater Reservoir area will likely not be entirely eliminated and there will still be a load from the contaminated sediments located within the Unnamed Reservoir area.

Predicted water quality in the downstream environment over the 2010-2150 period is shown in Figures 2.6-22, 2.6-23 and 2.6-24. Although contaminant concentrations from Minewater Reservoir are elevated the flow from this area is ephemeral, resulting in relatively small loadings. As a result significant improvements in water quality within the Meadow Fen, Greer Lake or Fulton Bay are not seen. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.6-25, 2.6-26 and 2.6-27 for the Meadow Fen, Greer Lake and Fulton Bay as compared to the base case, with no remediation. As can be seen, backfilling Minewater Reservoir does not change the exceedances predicted in the Meadow Fen, Greer Lake or Fulton Bay of Beaverlodge Lake.

Costs of backfilling activities were estimated by SENES & SRK (2012) to be approximately $1.9 million CAD.

Figure 2.6-22 The Meadow Fen Water Quality Predictions (Backfill Minewater Reservoir)

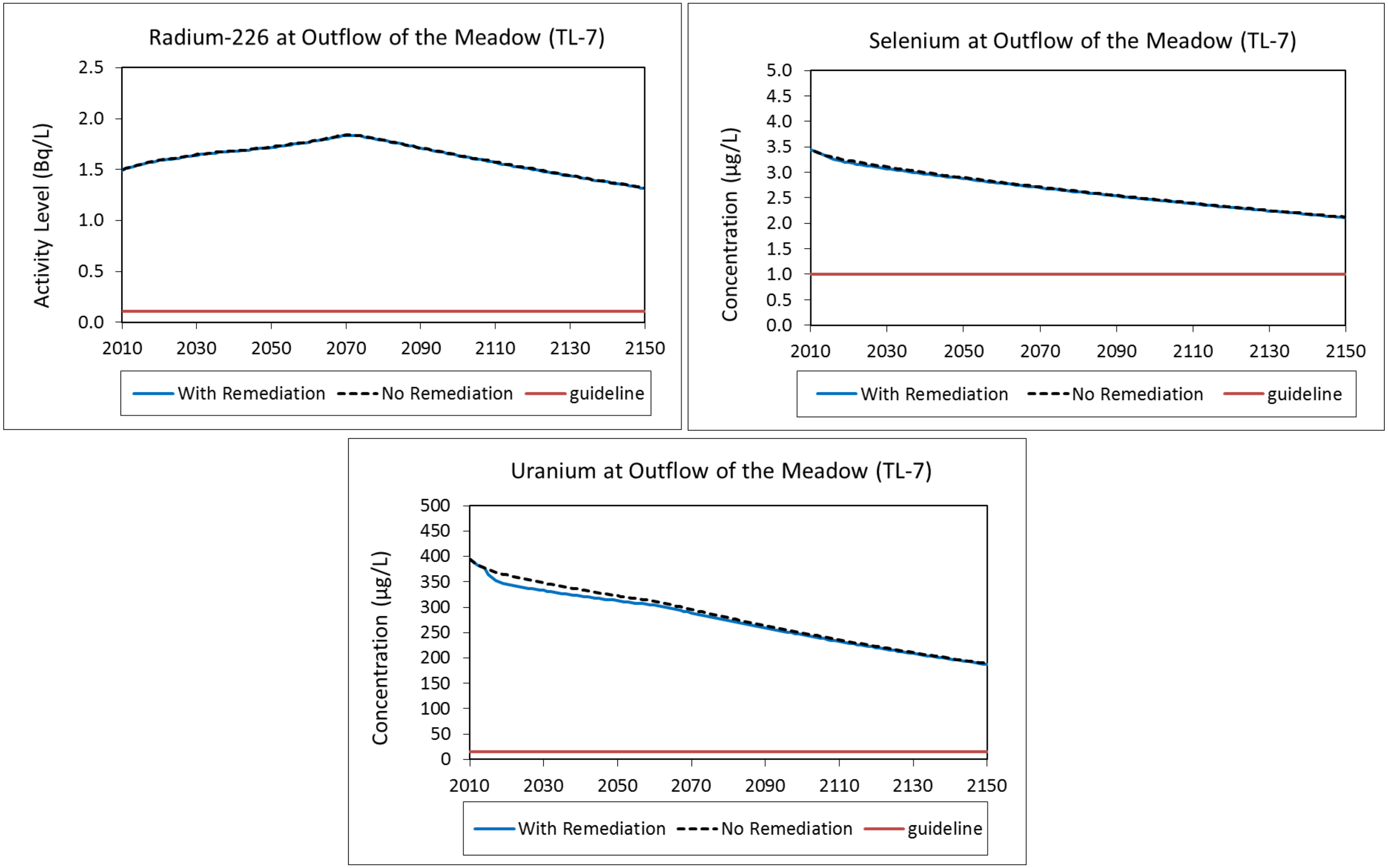


Figure 2.6-23 Greer Lake Water Quality Predictions (Backfill Minewater Reservoir)

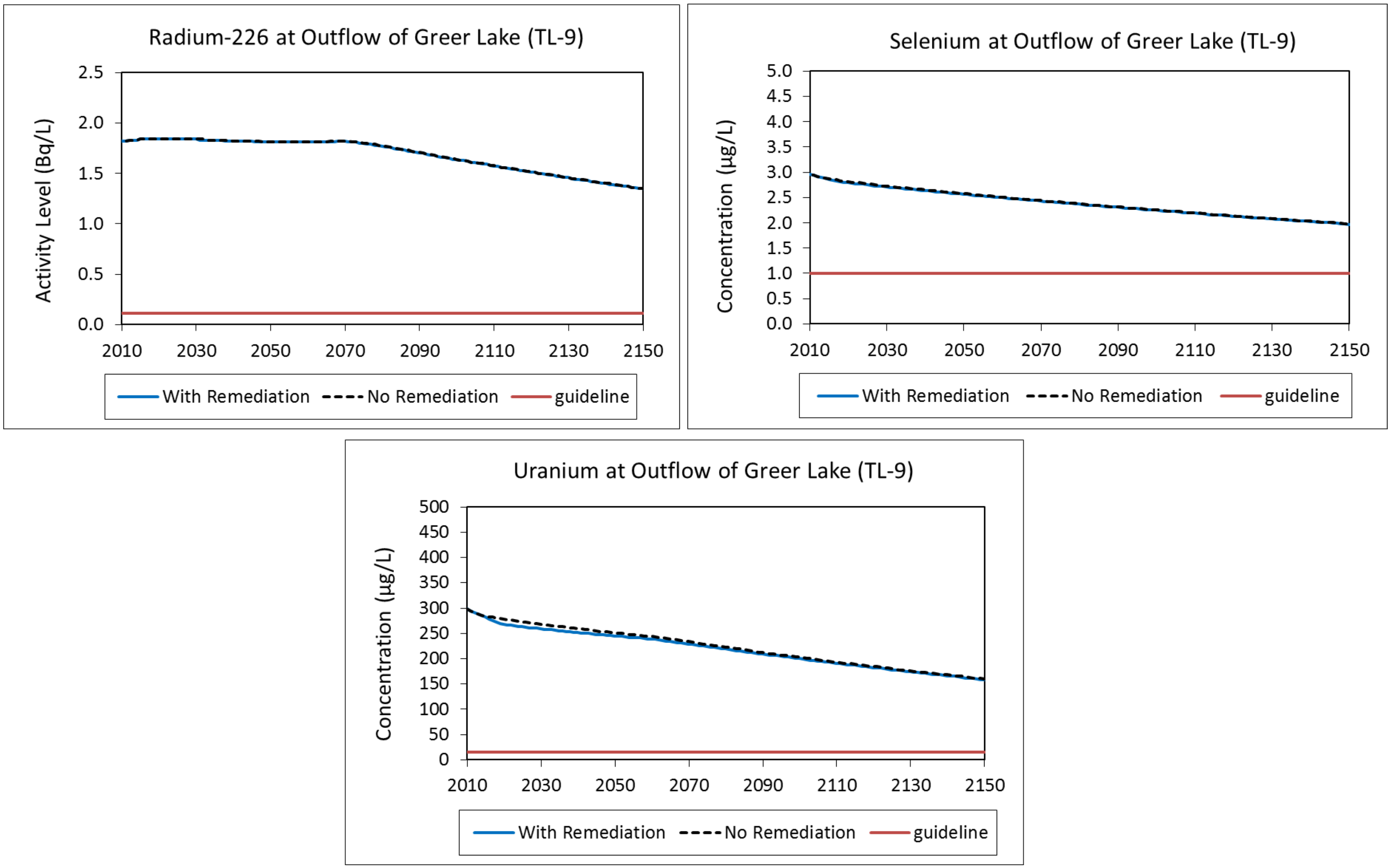


Figure 2.6-24 Fulton Bay, Beaverlodge Lake Water Quality Predictions (Backfill Minewater Reservoir)

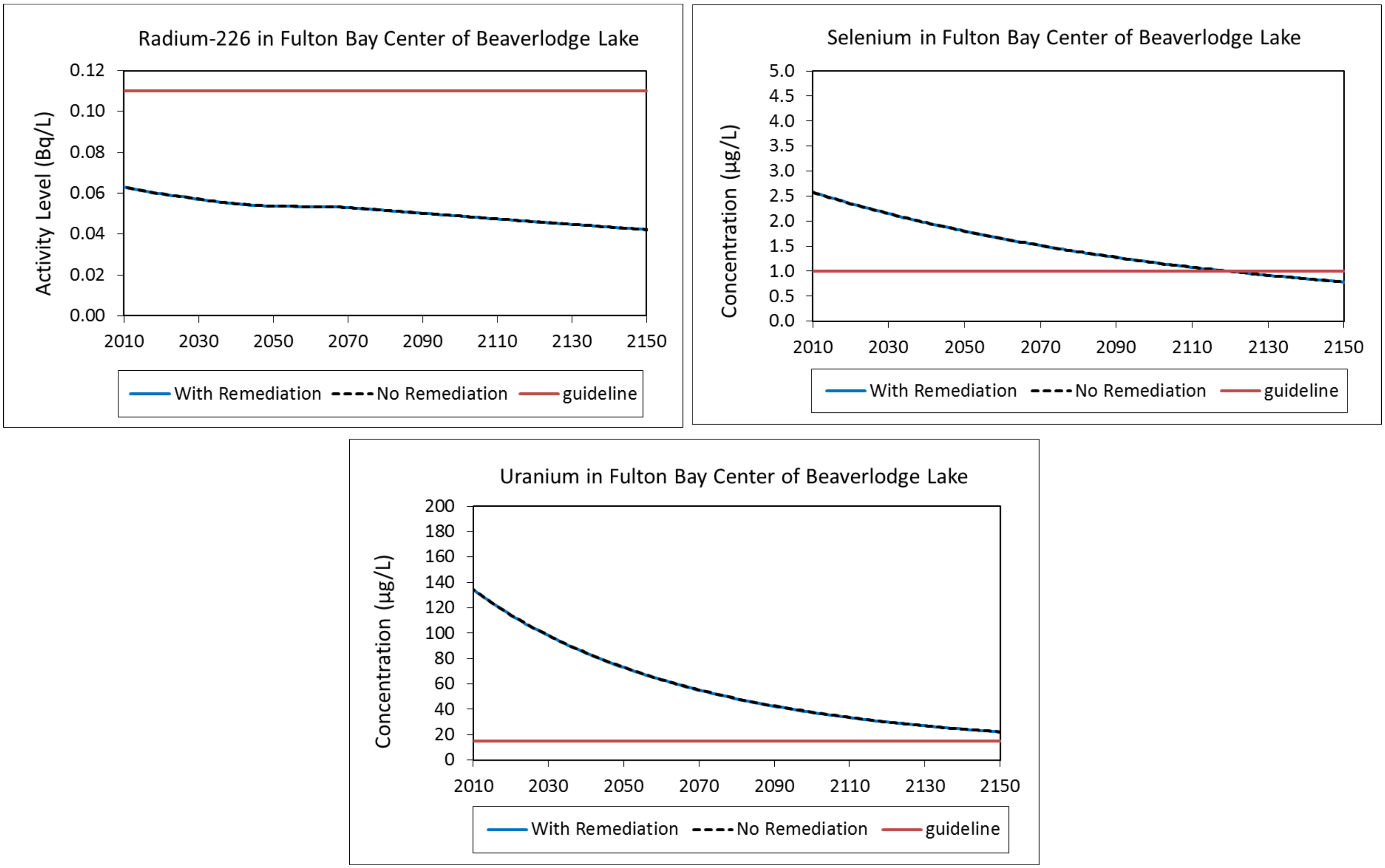


Figure 2.6-25 Summary of Outcomes in the Meadow Fen (Backfill Minewater Reservoir)

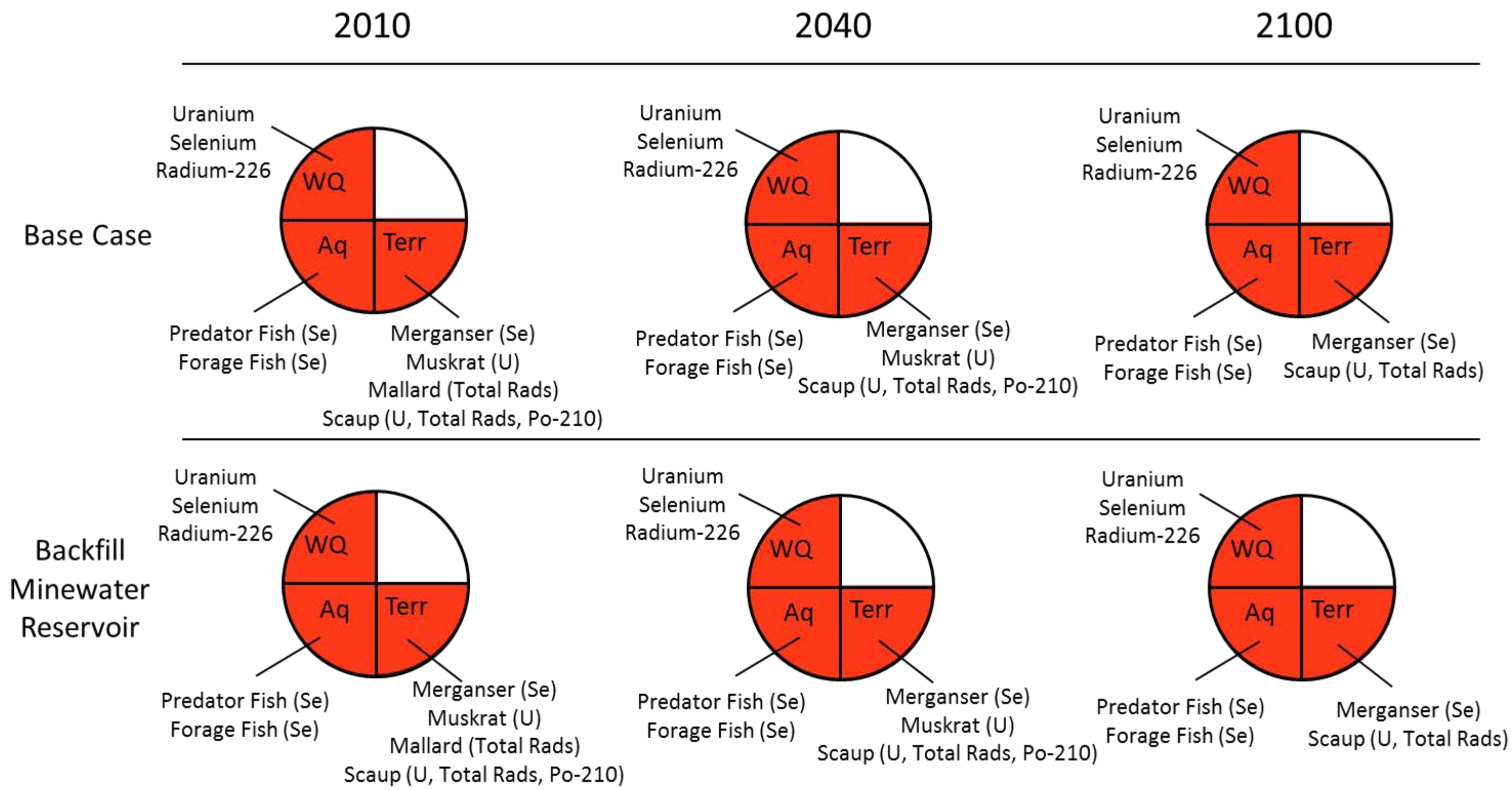


Figure 2.6-26 Summary of Outcomes in Greer Lake (Backfill Minewater Reservoir)

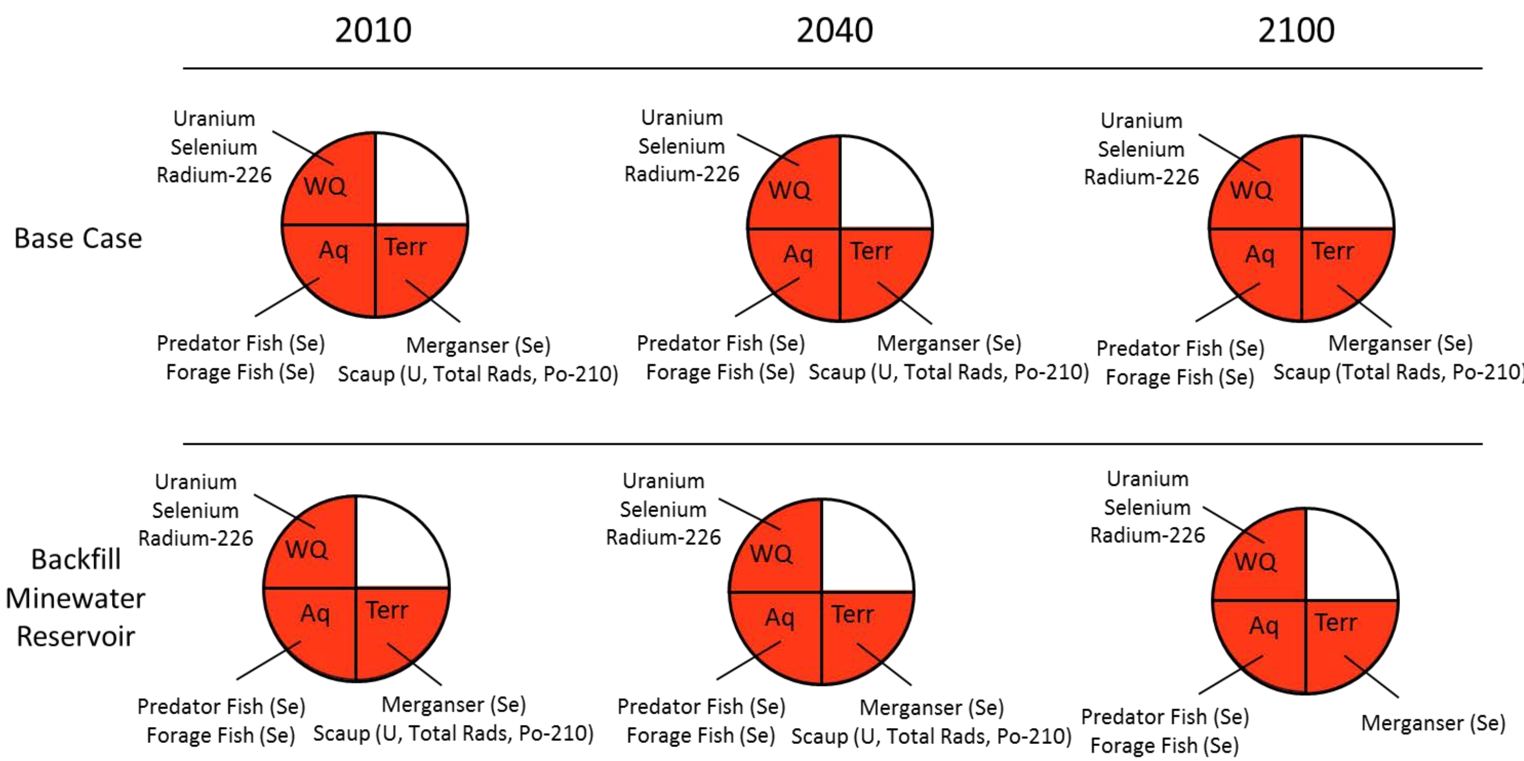
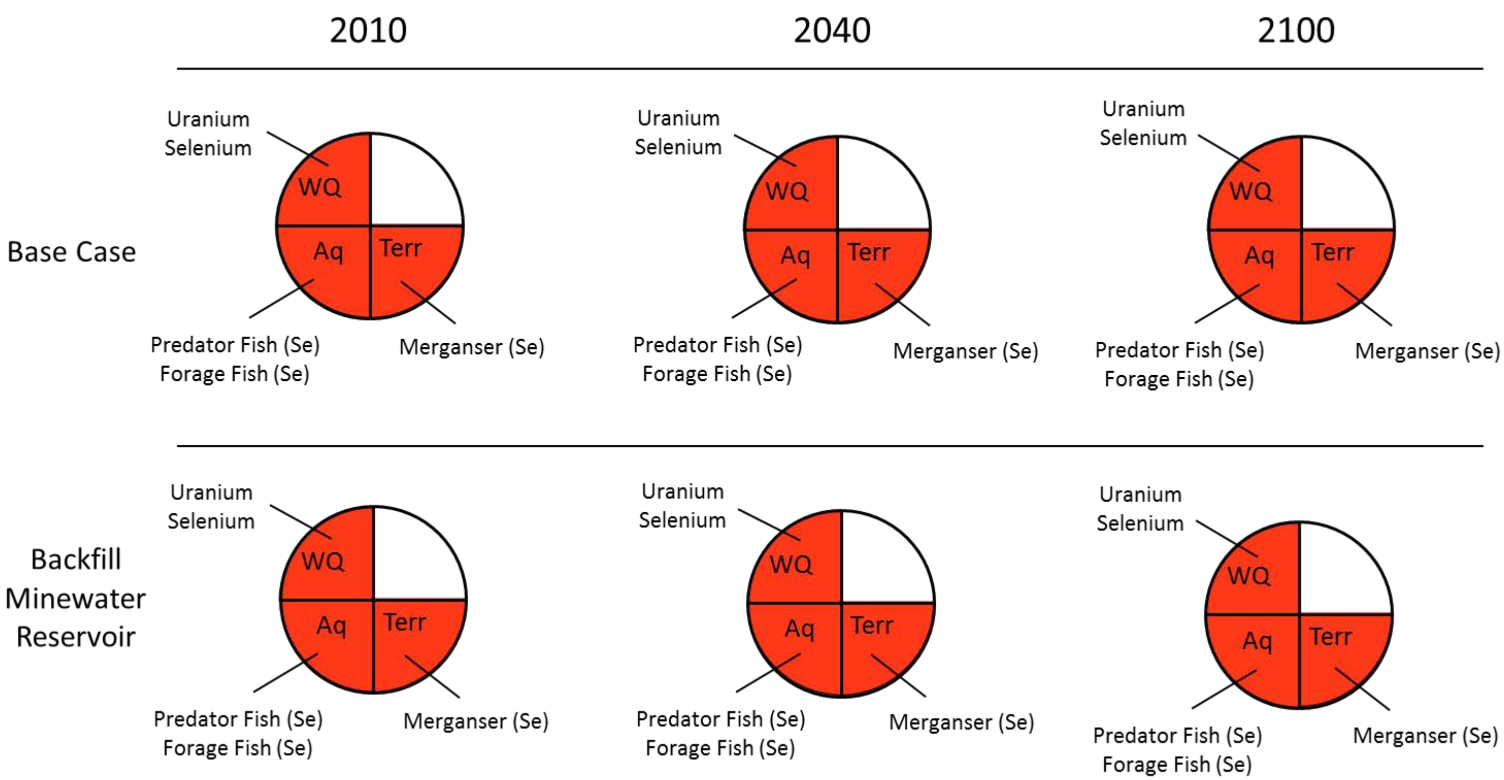


Figure 2.6-27 Summary of Outcomes in Fulton Bay, Beaverlodge Lake (Backfill Minewater Reservoir)



2.6.3.6 Flood Minewater Reservoir Area

This activity involves flooding the Minewater Reservoir area with water. The purpose of this remedial measure is to cover exposed tailings and impacted sediments that have become exposed over time within this area to reduce the associated gamma fields. A dam would be required at the current outlet of Minewater Reservoir and the existing dam structures keeping flow from exiting towards the Ace Creek Watershed would need to be upgraded, with both dams being maintained long-term as part of this remedial measure. In order to introduce additional water to the Minewater Reservoir area, water would be allowed to accumulate naturally over time or additional water could be pumped from the Lower Ace Creek area.

Potential effects of filling the Minewater Reservoir area with water were not assessed using the Beaverlodge QSM (SENES 2012a) as the outcomes of this measure are uncertain. It is predicted that this measure, while reducing the gamma fields in the area, would likely result in an increase in contaminants within the waters of Minewater Reservoir. This remedial measure is not expected to affect downstream water quality.

The costs of flooding the Minewater Reservoir area were estimated to be approximately $100,000 CAD including the NPV of an annual dam maintenance cost of $10,000 CAD.

2.6.3.7 Water Treatment at the Outlet of Greer Lake

This activity involves installation of a water treatment system and associated dam structure at the outlet of Greer Lake. The Beaverlodge Costing Report (SENES & SRK 2012) looked at long-term removal of radium-226, selenium and uranium as well as radium-226 alone. The system for removing radium-226 alone would be an ion exchange facility while the investigated system for removal of all three constituents is an on-site reverse osmosis plant with evaporation. Disposal of the used resin would be in an on-site burial trench within the tailings basin while the salt from the brine evaporation would be disposed of on-site in a lined repository. Disposal of these waste materials would likely require additional regulatory approval. Both systems would be designed with an operating capacity of 587,000 m^3/yr over an operating period of 200 days/yr. Details of these systems are provided in SENES & SRK (2012).

Potential effects of treating for radium-226, selenium and uranium removal at the outlet of Greer Lake were assessed using the Beaverlodge QSM (SENES 2012a) assuming the installation of the treatment facilities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of this remedial activity are:

- Operating capacity of water treatment system is 587,000 m^3/yr, with additional water being discharged downstream untreated
- System able to achieve concentrations of:
    - Radium-226: 0.11 Bq/L
    - Selenium: 1 µg/L
    - Uranium: 10 µg/L

Over the first 50 years of implementation, these assumptions result in a predicted reduction in radium-226 load of 84% from 1.2×10^6 kBq/yr to 1.8×10^5 kBq/yr, a reduction in uranium load of 86% from 165 kg/yr to 22 kg/yr and a reduction in selenium load of 55% from 1.7 kg/yr to 0.8 kg/yr to the downstream environment. However, after 50 years of operation, either an additional investment will be required to maintain/replace the treatment facility or the load to the downstream environment following operation will be the same as the base case scenario 50 years out.

Predicted water quality in the downstream environment (Fulton Bay and Beaverlodge Lake West) over the 2010-2150 period is shown in Figures 2.6-28 and 2.6-29. Water treatment at the outlet of Greer Lake is not expected to impact water quality within the Fulton Creek Watershed and is not shown. There is some predicted improvement in radium-226 levels in the water column of Beaverlodge Lake (both Fulton Bay and the main west segment). It should be noted, however, that average radium-226 levels in Beaverlodge Lake are predicted to be below the applicable water quality guideline even without the implementation of this treatment plant. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.6-30 and 2.6-31 for Fulton Bay and west segment of Beaverlodge Lake as compared to the base case, with no remediation. As can be seen, implementation of this water treatment does not change the exceedances predicted in Fulton Bay or the Beaverlodge Lake west main segment.

It should be noted that this remediation activity involves perpetual maintenance of the water treatment system and associated dam structure at the outlet of Greer Lake.

Costs of installation as well as long-term operation and maintenance of the water treatment plant at the outlet of Greer Lake were estimated by SENES & SRK (2012) to be approximately $26.0 and $55.4 million CAD for treatment of radium-226 alone and all three constituents, respectively. These costs include the NPV of an annual operating and maintenance cost of between $670,000 and $990,000 CAD.

Figure 2.6-28 Fulton Bay, Beaverlodge Lake Water Quality Predictions (Water Treatment at Greer Lake Outlet)

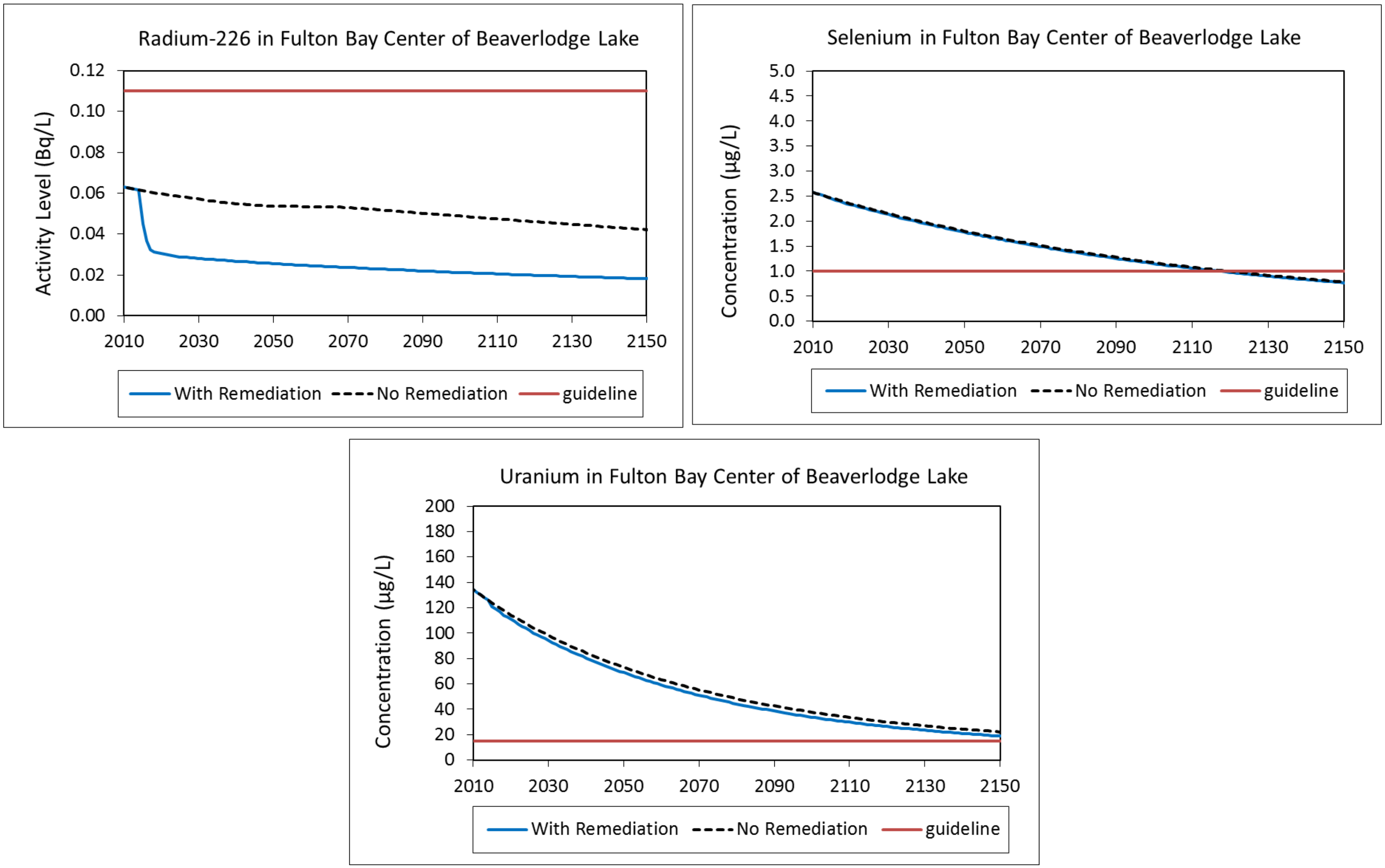


Figure 2.6-29 Beaverlodge Lake West Water Quality Predictions (Water Treatment at Greer Lake Outlet)

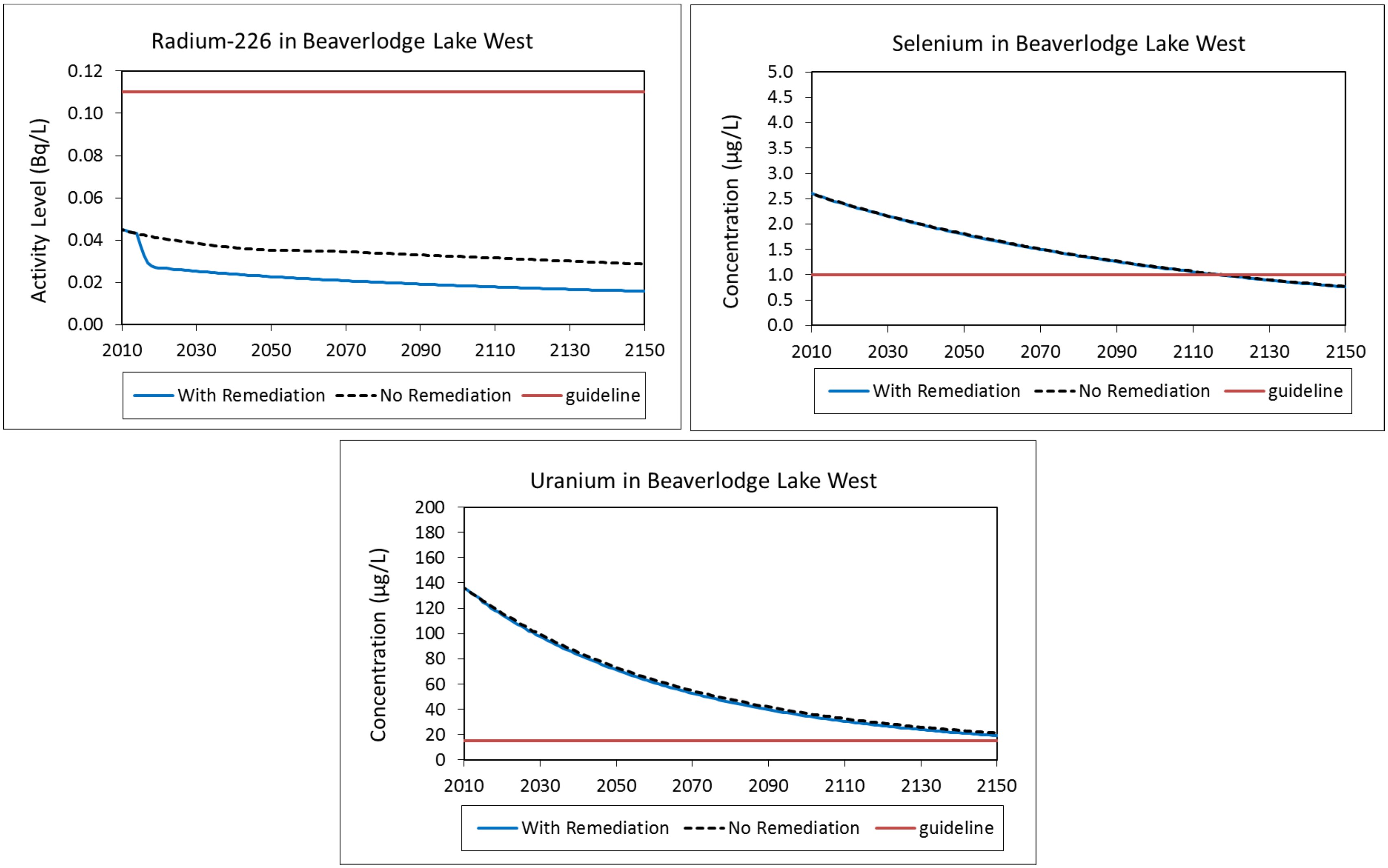


Figure 2.6-30 Summary of Outcomes in Fulton Bay, Beaverlodge Lake (Water Treatment at Greer Lake Outlet)

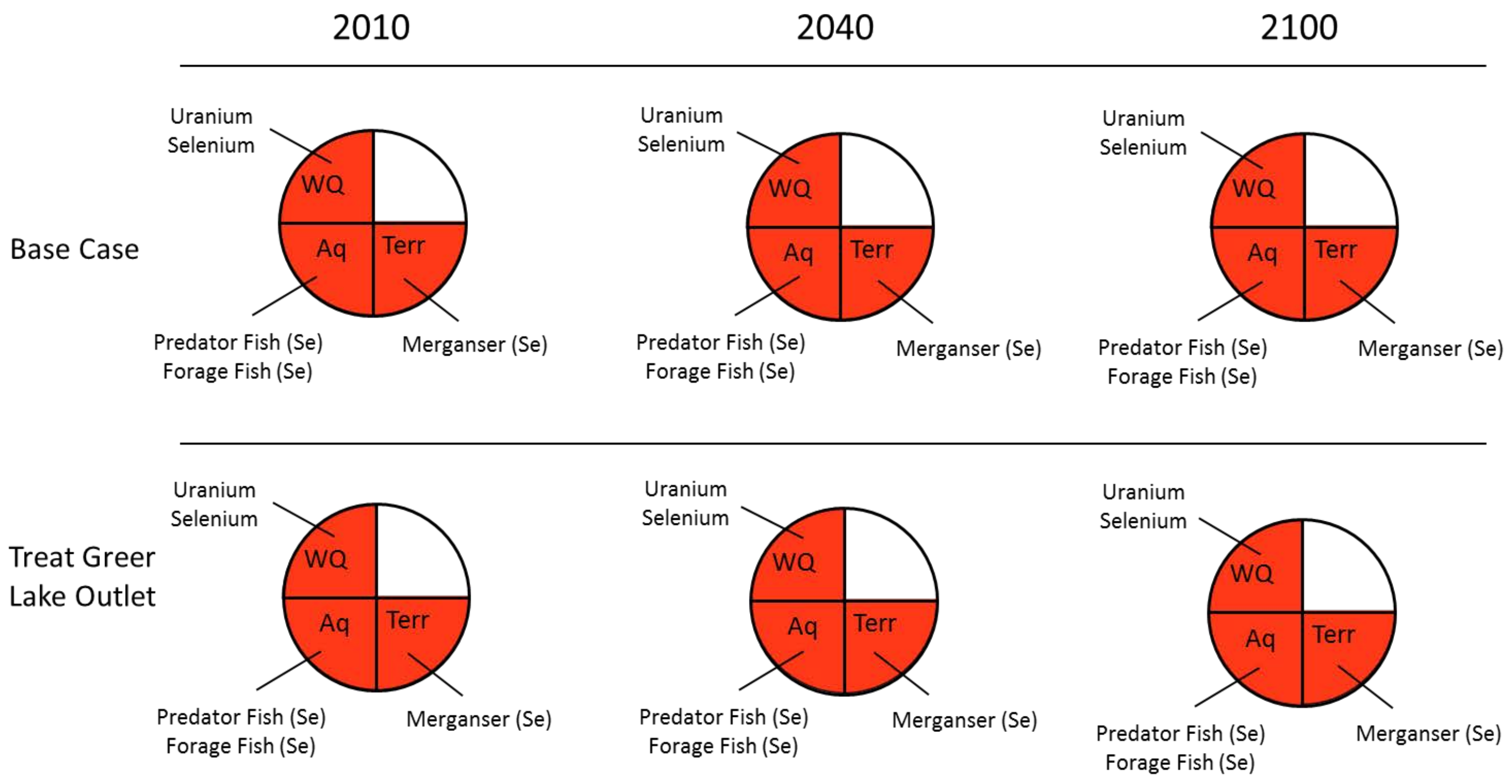
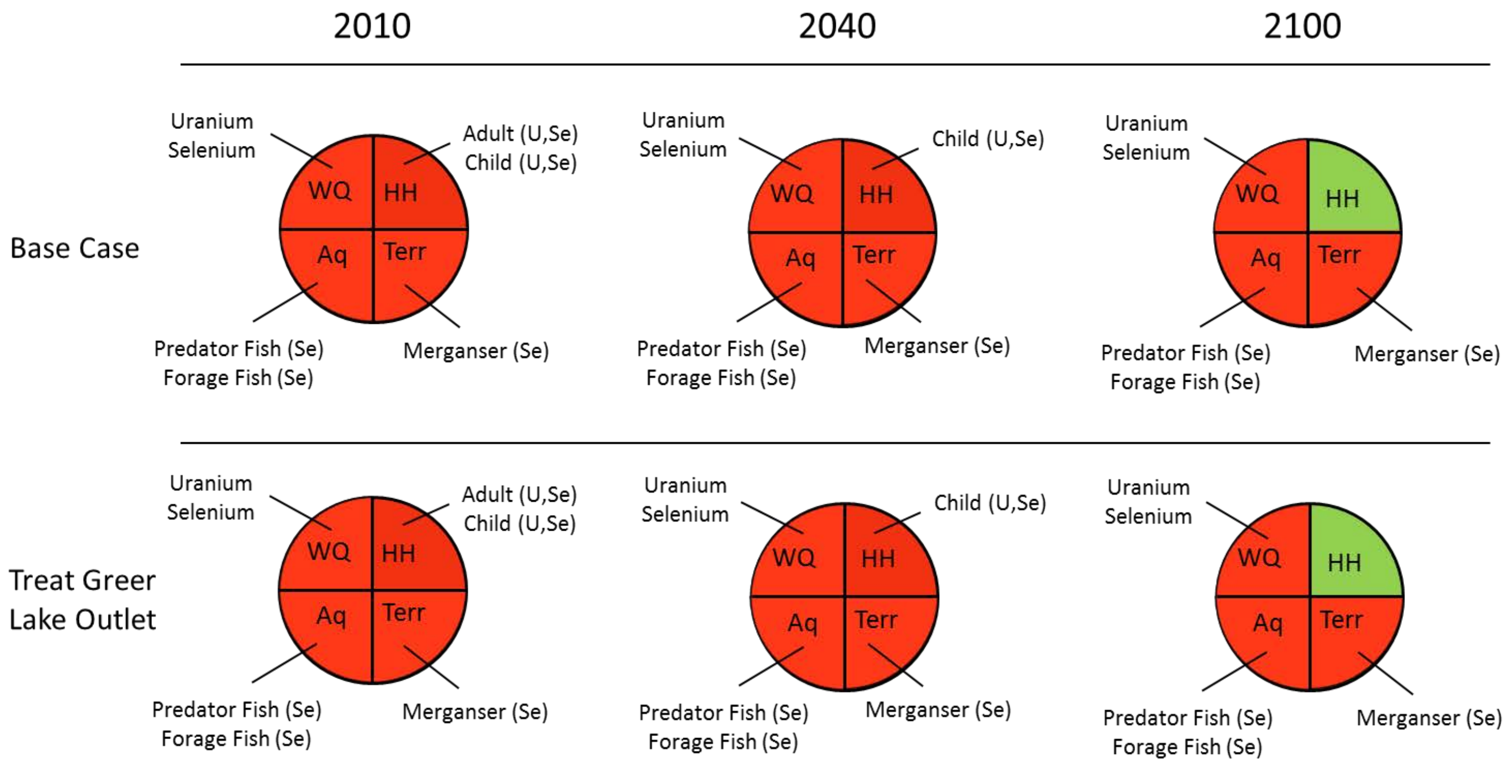


Figure 2.6-31 Summary of Outcomes in Beaverlodge Lake West (Water Treatment at Greer Lake Outlet)



2.6.4 Fulton Creek Watershed Selection of Remedial Activities

In addition to predicted changes to the environment as assessed by the Beaverlodge QSM (SENES 2012a) and estimated costs of assessed activities (SENES & SRK 2012), opinions expressed during the Beaverlodge Remedial Option Workshop (ASKI, SENES & SRK 2012) can be used as additional information to help inform the remedial activity evaluation process. Outcomes from these three sources are discussed below. In addition, the costs and benefits for each of the remedial measures considered for the Fulton Creek Watershed are summarized in Table 2.6-2. For each remedial activity expected change to exceedances, predicted reduction in loads, estimated costs as well as calculated cost per unit reduction are presented.

Table 2.6-2 Summary of Predicted Effects of Remedial Activities, Fulton Creek Watershed

Remedial Measure	Change to Water Quality or Human/Eco Risk?[a]	Reduction in Load to Downstream Environment[b]			Estimated Costs (CAD)	Cost per Unit Reduction[b]			Comments
		Ra-226 (MBq/yr)	Se (kg/yr)	U (kg/yr)		Ra-226 (CAD/kBq/yr)	Se (CAD/g/yr)	U (CAD/g/yr)	
Divert Fulton Lake outflow around BTMA	no change to exceedances	431 (37%)	0.7 (42%)	73.9 (45%)	$13,00,000 to $23,800,000	55	33,000	320	-predicted effect on contaminant loads to Beaverlodge Lake minimal -results in decreased water quality within isolated lakes -requires ongoing maintenance of dam structures
Cover sediments within the Fulton Creek Watershed	Some reduction in exceedances for terrestrial receptors in Fookes Reservoir, the Meadow Fen and Greer Lake	646 (56%)	0.8 (48%)	59.6 (36%)	$27,000,000 to $27,900,000	43	35,000	470	-predicted effect on contaminant loads to Beaverlodge Lake minimal
Dredge sediments within the Fulton Creek Watershed	not assessed	-	-	-	$34,500,000 plus additional cost of isolating dredged sediments	-	-	-	- uncertainty regarding feasibility -would likely require ongoing maintenance of dam structures and/or a water treatment system
Cover easily accessible non-aqueous tailings within the Fulton Creek Watershed	no change to exceedances	-	-	-	$1,000,000	-	-	-	-predicted effect on contaminant loads to the immediate and downstream environment minimal -reduces the potential for gamma exposure by receptors frequenting the site
Backfill Minewater Reservoir	no change to exceedances	0.8 (0.1%)	0.01 (0.5%)	4.6 (3%)	$1,900,000	2,500	210,000	410	-predicted effect on contaminant loads to downstream environment minimal
Flood Minewater Reservoir area	no change to exceedances	-	-	-	$100,000	-	-	-	-not expected to significantly increase or decrease contaminant loads to downstream environment -reduces the potential for gamma exposure by receptors frequenting the site
Water Treatment at the outlet of Greer Lake	no change to exceedances	973 (84%)	0.9 (55%)	142 (86%)	$26,000,000 to $55,400,000	57	60,000	390	-cost of water treatment at the outlet of Greer Lake unjustifiably high -predicted effect on contaminant loads to Beaverlodge Lake minimal with exception of radium-226 -additional regulatory licensing requirement -requires ongoing operation and maintenance of treatment facility

Notes: [a] human receptors assessed at Beaverlodge Lake west segment but not Fulton Bay of Beaverlodge Lake
[b] load reductions estimated over the first 50 years after implementation

Diverting Fulton Lake outflow around the BTMA is predicted to provide some benefit to water quality in the downstream environment. It should be noted, however that the downstream reductions are for radium-226, which is already below the applicable guideline without remediation and is predicted to remain there. As expected, water quality within the isolated lakes is predicted to suffer as a result of diverting the Fulton Lake outflow. This stream diversion was discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). Stakeholders generally agreed that stream diversion in the Fulton Creek Watershed has no role in further remediation of the former Eldorado Beaverlodge properties. In addition to the high cost of this diversion, there would be a significant requirement for blasting, it may have a significant effect on fish habitat in this watershed system, would greatly alter the regional landscape, and would require ongoing maintenance of the constructed dam and channel structures.

Covering sediments within the Fulton Creek Watershed are predicted to have a long term benefit to water quality within the remediated water bodies and a short term detriment. It should be noted that the predictions generated using the Beaverlodge QSM assume that a good cover is achieved and the covered sediments remain relatively isolated, these results are likely optimistic as an effective cover may not be established in all water bodies. Even with effective application of a sediment cover, constituents within impacted sediments would still be released over time. There is no predicted reduction of selenium or uranium levels in Fulton Bay of Beaverlodge Lake as a result of this remedial activity. Fulton Creek Watershed sediment cover was discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). During discussions stakeholders raised many concerns relating to technical uncertainties including the fact that, due to the organic nature of the sediments, it may be quite difficult to place a sand cover. Additionally, concerns were raised that these activities would have a negative short term impact to these lakes resulting in a disturbance of the existing benthic community. It was also noted that these sediment covers would require a large amount of borrow material which may be needed for other activities. Due to the considerable risk related to the many technical uncertainties in combination with the high cost of implementation and the lack of benefit predicted in Beaverlodge Lake, covering sediments within the Fulton Creek Watershed is not justified.

The success of dredging impacted sediments from waterbodies of the Fulton Creek Watershed for removal to Fookes Reservoir is uncertain. In addition to questions regarding the feasibility of collecting light organic sediments in this way, there is also uncertainty regarding the ability to effectively isolate deposited sediments within Fookes Reservoir to reduce re-contamination of downstream sediments. In addition, there would be a detrimental short term impact on ecological habitat upon implementation. It is for these reasons that this measure was not included in any remedial scenarios discussed during the Beaverlodge 2012 Remedial Options

Workshop (ASKI, SENES & SRK 2012). Due to the extremely high cost and uncertainty regarding success and impact on the environment, this option was not further considered by Cameco.

Cover of non-aqueous tailings within the Fulton Creek Watershed is an activity which is not anticipated to affect water quality within any of the nearby waterbodies. It is, however, expected to limit surface gamma release and likely reduce potential gamma exposure to human and ecological receptors frequenting the area. This remedial activity would deal primarily with application of a sand cover to the waste rock cover already in place at Marie Reservoir tailings delta, in the area surrounding Minewater Reservoir and other accessible areas within the Fulton Creek drainage that contain exposed tailings. Because this option is not anticipated to have any effect on local or regional waterbodies, this remedial activity was not discussed during the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012).

As discussed previously, the flow through the Minewater Reservoir area is ephemeral in nature which results in very minor loads from this area to the downstream environment compared to other sources. As a result very little benefit is predicted to the downstream environment as a result of backfilling the Minewater Reservoir area. In addition, this activity would require a very large amount of borrow material. Due to the fact that very little benefit is realized in exchange for fairly high costs, both monetary and natural resource usage, this activity is not considered to be justified and was not discussed in detail during the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012).

Flooding the Minewater Reservoir area was examined as a potential way to reduce gamma fields associated with areas of exposed tailings. This activity will likely see the water quality within Minewater Reservoir deteriorate and does not improve the water quality in the downstream environment. Flooding the Minewater Reservoir area was not discussed during the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012) as similar reductions in the local gamma fields can be realized through sand cover of exposed tailings without requiring ongoing maintenance of dam structures for likely a fraction of the cost.

Water treatment at the outlet of Greer Lake is predicted to improve radium-226 levels in Beaverlodge Lake; however, radium-226 within this region was predicted to be below the applicable surface water quality guideline prior to any remedial activities. Water treatment at the outlet of Greer Lake was discussed during the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). Stakeholders raised concerns that this treatment plant would be relatively high cost with little or no improvement to water quality in the upstream or downstream environments; it requires active, long-term operation and maintenance; the process produces a contaminated salt that must be managed and stored as a hazardous waste; and the ability to treat to the low levels required is largely unproven. The limited benefit achieved is not considered to be justified given the extraordinarily high cost of implementation and long-term operation and maintenance.

Based on the evaluation presented above, the recommended course of action developed by Cameco for the Fulton Creek Watershed is to continue monitoring the area to ensure that recovery is progressing as expected and to cover accessible tailings in the following areas: the Marie Reservoir tailings delta, areas around Minewater Reservoir that show elevated gamma radiation and tailings spills along the former tailings lines. The other considered activities are not recommended primarily due to the fact that little benefit is seen to the downstream environment for the relatively high associated costs.

2.7 BEAVERLODGE LAKE AREA

Beaverlodge Lake is the receiving environment for water from the Ace Creek and Fulton Creek watersheds. Water from the Ace Creek Watershed enters Beaverlodge Lake through Ace Bay while water from the Fulton Creek Watershed is discharged into Fulton Bay before entering Beaverlodge Lake. Water from Beaverlodge Lake exits into Martin Lake which the flows through Cinch Lake and Crackingstone River to Lake Athabasca. The Beaverlodge Lake area is shown in Figure 2.7-1.

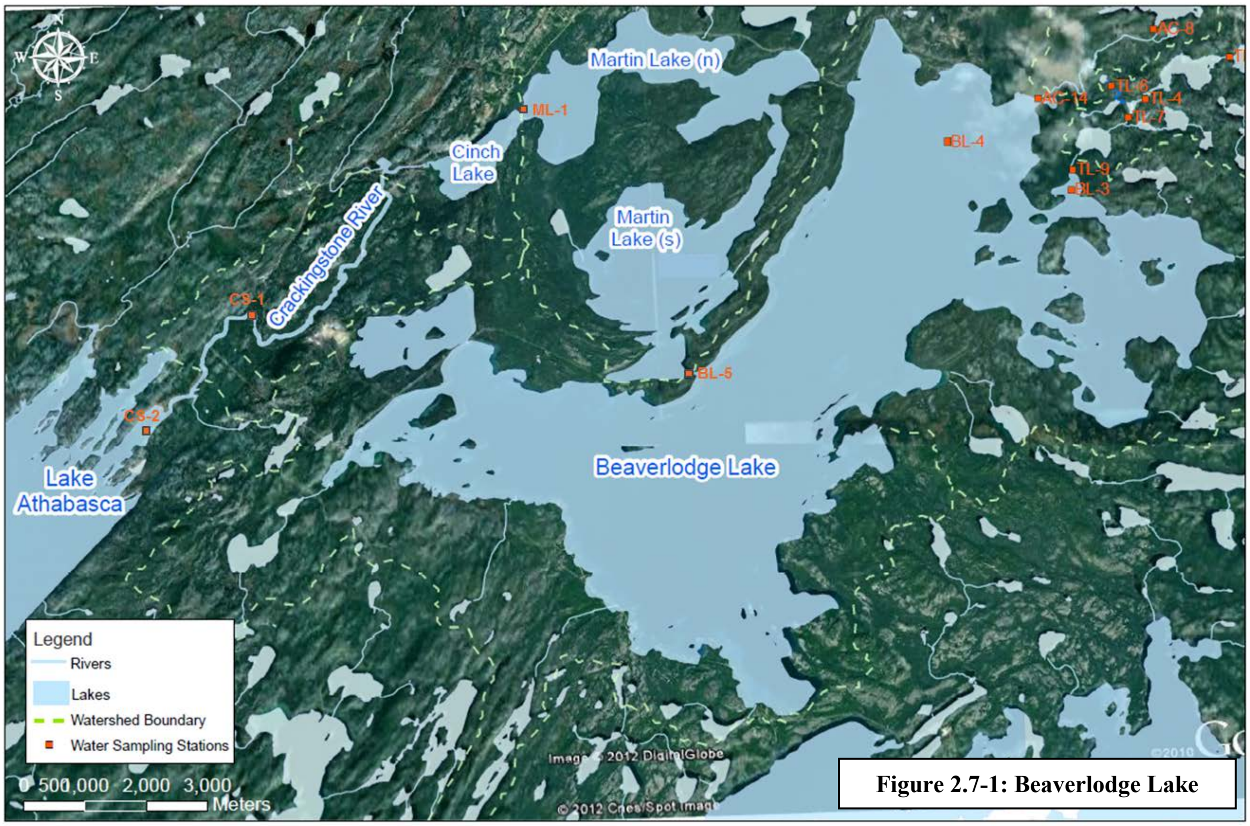


Figure 2.7-1: Beaverlodge Lake

2.7.1 Beaverlodge Lake Area Features

As previously noted, the quality of both water and sediments in Beaverlodge Lake were affected by effluent discharges and spills during the operating life of the mine. Monitoring of sediment quality in Ace Bay indicates that these sediments have similar geochemical characteristics as tailings, which is not surprising as there were several tailings spills in the watershed during the operating life of the mine. Sediments in Fulton Bay on the other hand were influenced by both carryover of tailings solids from the BTMA during the operating life of the mine, as well as, carryover of chemical precipitates from the water treatment system during the later years prior to mine closure. It should be noted that other historical mining and milling operations also affected water and sediment quality in Beaverlodge Lake.

2.7.2 Beaverlodge Lake Area Assessment of Potential Risks

In order to select remedial measures, the potential risks that various features within the Beaverlodge Lake area may pose to the environment and members of the public accessing the site were assessed. Site aspects examined included mining geotechnical; surface water; contaminated substrate; air, radon and gamma; aquatic vegetation; and risk communication. When determining a relative risk rating for each site element the likelihood of the event occurring as well as the consequence of that event were considered. The resulting relative risk estimates for the Beaverlodge Lake area are shown in Table 2.7-1.

Table 2.7-1 Summary of Estimated Risks, Beaverlodge Lake Area

Aspect	Specific Location	Site Element	Current Risk Registry		Risk Endpoints		References
			Event	Effect	Environment Risk	Public Health and Safety Risk	
Mining Geotechnical	-	-	None identified	-	-	-	Screening Level Risk Assessment, Cameco 2010b.
Surface Water	**Ace Bay**	**Spills, subaqueous tailings, upstream sources and sediments**	Historic spills and continuing release from sediment and other sources	Impact on Ace Bay and Beaverlodge Lake water quality and ecosystem effects	**ML**	**L**	Beaverlodge Quantitive Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009.
	Fulton Bay	**Spills, subaqueous tailings, upstream sources and sediments**	Historic and continuous releases from the BTMA, sediments and other sources	Impact on Fulton Bay and Beaverlodge Lake water quality and ecosystem effects	**ML**	**L**	Beaverlodge Quantitive Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009.
	Beaverlodge Lake	**Loads to Beaverlodge Lake**	Releases from the Ace Creek and Fulton Creek Watersheds as well as non-Beaverlodge sources	Impact on Beaverlodge Lake water quality and ecosystem effects	**ML**	**ML**	Beaverlodge Quantitive Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009.
		Beaverlodge Lake Water	Discharge from Beaverlodge Lake to downstream waters	Impact on downstream water quality	**M**	**M**	Beaverlodge Quantitive Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009.
Contaminated Substrate	**Ace Bay**	**Sediment Substrate**	Accumulation of COPC in sub-aqueous sediments and tailing deposited during operations	Impact on Ace Bay and Beaverlodge Lake water quality	**MH**	**ML**	Beaverlodge Quantitive Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009. Ace Bay Sediment and Benthic Invertebrate sampling Program. CanNorth 2011b. Aquatic Macrophyte Sampling Program. CanNorth 2011a.
	Fulton Bay	**Sediment Substrate**	Accumulation of COPC in sub-aqueous sediments and tailing deposited during operations	Impact on Fulton Bay and Beaverlodge Lake water quality	**MH**	**ML**	Beaverlodge Quantitive Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009.
	Beaverlodge Lake	**Sediment Substrate**	Accumulation of COPC in sub-aqueous sediments and tailing deposited during operations	Impact on Beaverlodge Lake water quality	**MH**	**ML**	Beaverlodge Quantitive Site Model. SENES 2012a. Beaverlodge Integrated ERA and SOE. SENES 2009.
Air, Radon and Gamma	-	-	None identified	-	-	-	Screening Level Risk Assessment, Cameco 2010b.
Aquatic Vegetation	**Ace Bay**	**Vegetation**	Leaching of COPC to water	Potential uptake of contaminants in vegetation and impact to VECs	**M**	**ML**	Beaverlodge Quantitative Site Model. SENES 2012a. Aquatic Macrophyte Sampling Program. CanNorth 2011a. Country Foods Survey. SENES 2012b. Draft. Ace Bay Sediment and Benthic Invertebrate Sampling Program. CanNorth 2011b.
	Fulton Bay	**Vegetation**	Leaching of COPC to water	Potential uptake of contaminants in vegetation and impact to VECs	**M**	**ML**	
	Beaverlodge Lake	**Vegetation**	Leaching of COPC to water	Potential uptake of contaminants in vegetation and impact to VECs	**M**	**ML**	
Risk Communication	**General**	**-**	Public notification of any site risk	If not done in a timely manner may cause public safety risk	**L**	**ML**	Screening Level Risk Assessment, Cameco 2010b.

As can be seen within Table 2.7-1, potential events which were estimated to pose the greatest risk to the environment and public accessing the site include historical accumulation of COPC in sub-aqueous sediments and tailings deposited during operations, discharge of water to the downstream environment and uptake of COPC by aquatic vegetation; remedial measures examined within the following section are focused on these features. It should be noted that, with the exception of the historical accumulation of COPC within sub-aqueous tailings and sediments, none of these risks were assessed as being higher than a 'medium-high' ranking as described in the risk assessment provided in Table 2.7-1.

2.7.3 Beaverlodge Lake Area Assessment of Remedial Activities

Potential remedial measures considered based on identified risks within the Beaverlodge Lake area

- Cover sediments in Fulton and Ace bays
- Induce eutrophication and associated algal blooms within Beaverlodge Lake

These activities will be discussed in the following sections.

2.7.3.1 Cover Sediments within Fulton and Ace Bays

This activity involves applying a sand cover to sediments in Fulton and Ace bays of Beaverlodge Lake to act as a barrier to reduce the flux of contaminants from the sediment and also reduce contact of biota with contaminants present in the sediment porewater and solids. Covering of sediments would be achieved by pumping sand slurry onto the surface of these areas by barge. It is assumed that borrow materials for this activity would be locally sourced from previously identified areas (SENES & SRK 2012).

Potential change to environmental conditions based on covering sediments in the water bodies within Fulton and Ace Bays of Beaverlodge Lake was assessed using the Beaverlodge QSM (SENES 2012a) assuming the activities are completed in the year 2015 for modeling purposes.

Assumptions which were made in order to predict the effects of covering sediments in Fulton and Ace bays are:

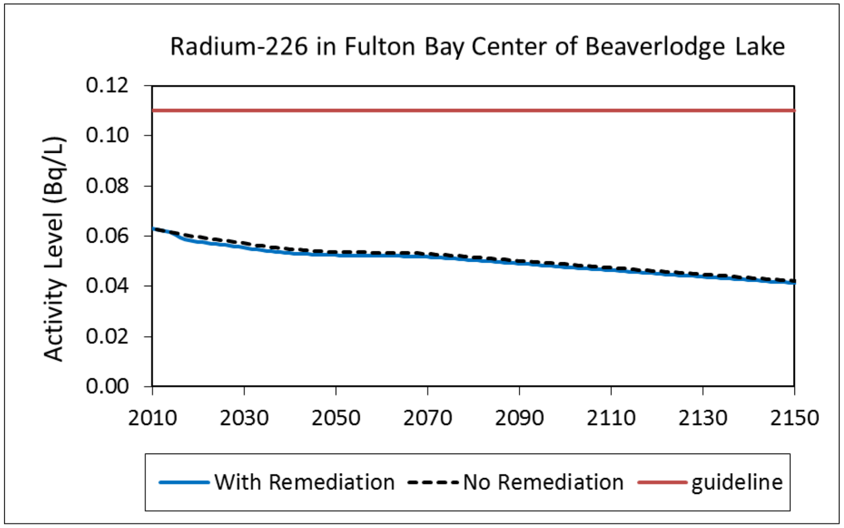
- Cover material assumed to be a typical sandy fill (porosity of 0.4 and tortuosity of 3).
- 10 cm of cover material placed, mixes with the top 5 cm of pre-existing sediments
- Able to effectively cover 95% of each bay

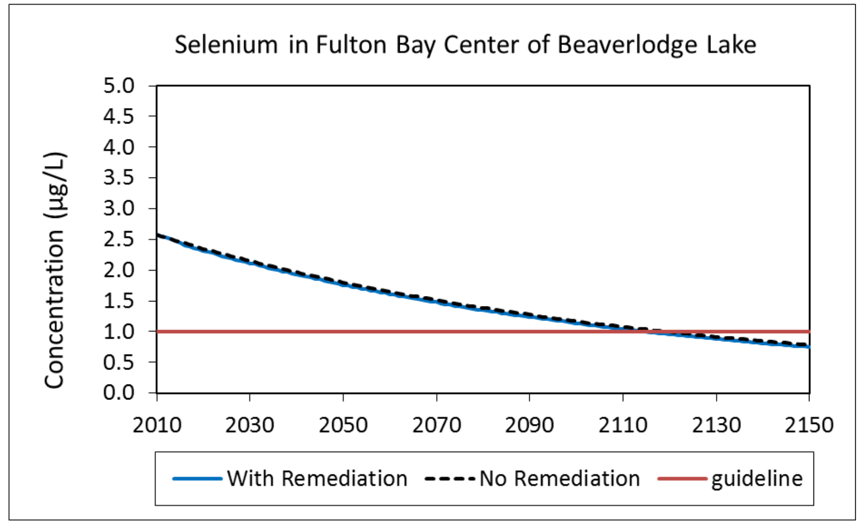
These assumptions result in a predicted reduction in radium-226 load of 3%, a reduction in uranium load of 1% and a reduction in selenium load of 1% to the downstream environment. It should be noted that this activity would also likely result in the almost complete destruction of the benthic community in the areas covered and it may take a decade or more for new communities to recolonize the covered areas.

Predicted water quality over the 2010-2150 period is shown in Figures 2.7-2, 2.7-3 and 2.7-4 for Fulton Bay, Ace Bay and the western region of Beaverlodge Lake, respectively. Almost no improvement to water quality is predicted within the modeled areas. This result is not surprising as this remedial activity only covers a very small fraction of the total impacted sediments within Beaverlodge Lake. A summary of the predicted exceedances of water quality guidelines and SI benchmarks for the considered receptors are shown in Figures 2.7-5, 2.7-6 and 2.7-7 for Fulton Bay, Ace Bay and the western region of Beaverlodge Lake as compared to the base case, with no remediation. As can be seen, implementation of this activity is not predicted expected to change any expected exceedances within these areas.

Costs of applying this sand cover to sediments in Fulton and Ace bays of Beaverlodge Lake were estimated by SENES & SRK (2012) to be approximately $29.3 Million CAD.

Figure 2.7-2 Fulton Bay, Beaverlodge Lake Water Quality Predictions (Cover Fulton and Ace Bay Sediments)





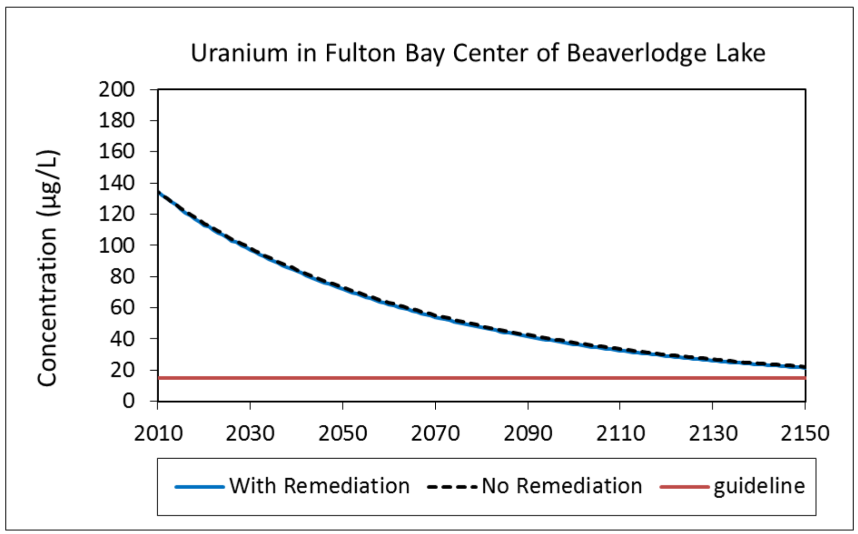


Figure 2.7-3 Ace Bay, Beaverlodge Lake Water Quality Predictions (Cover Fulton and Ace Bay Sediments)

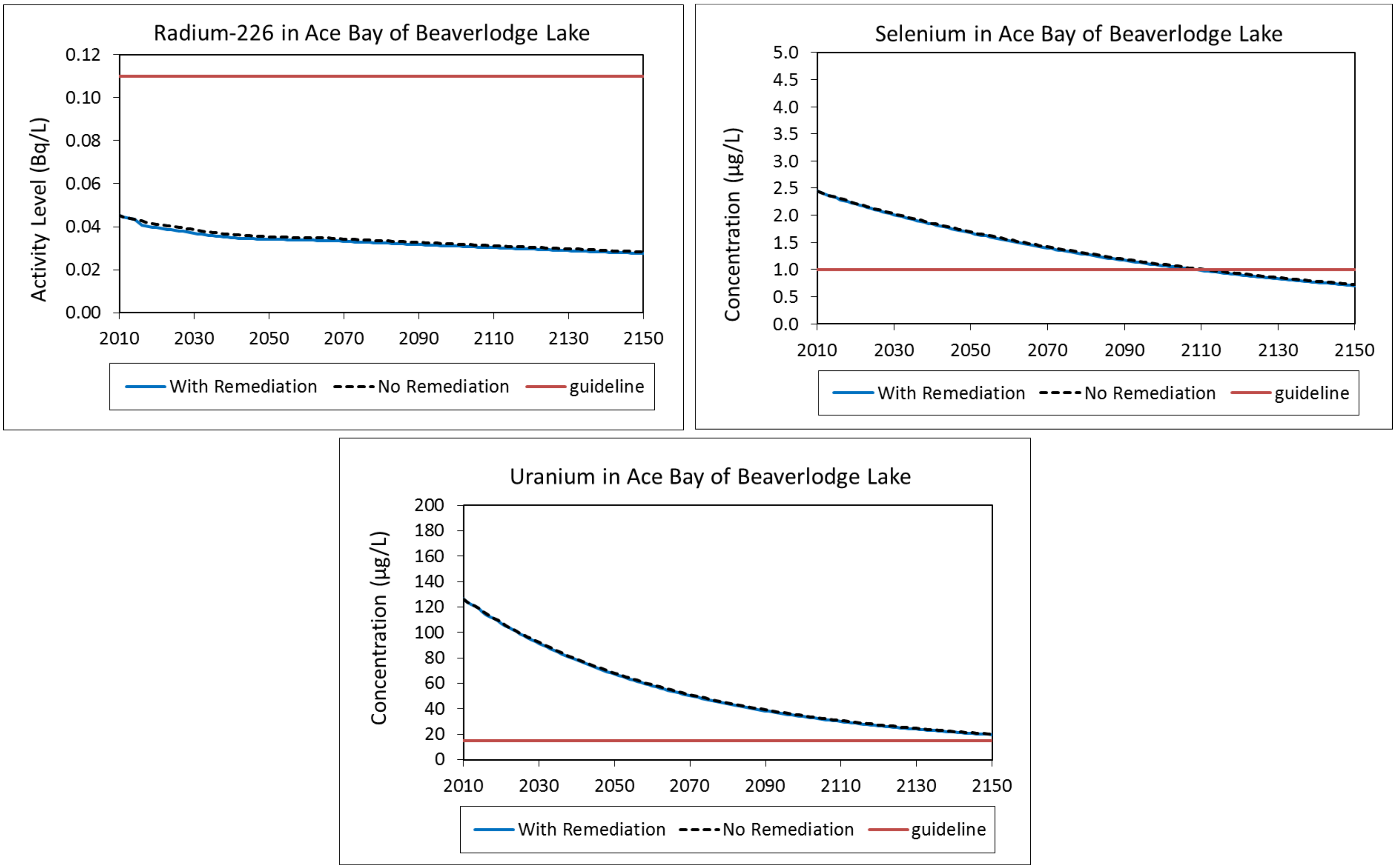
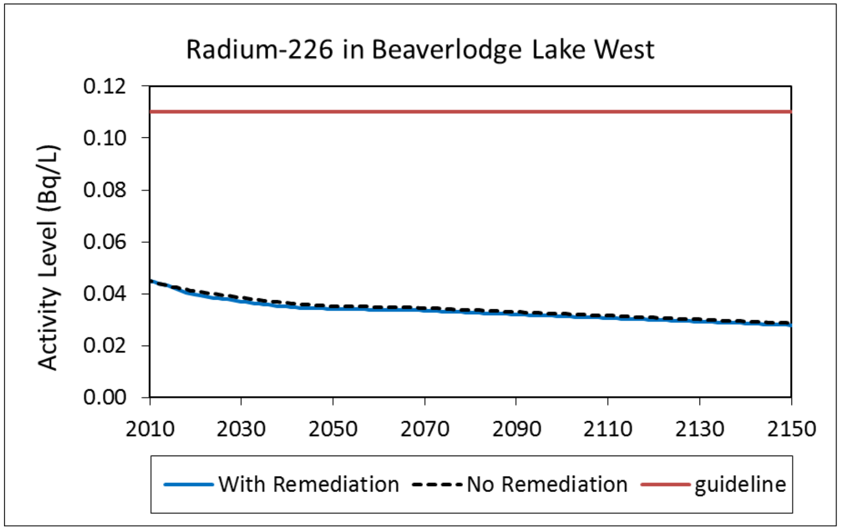
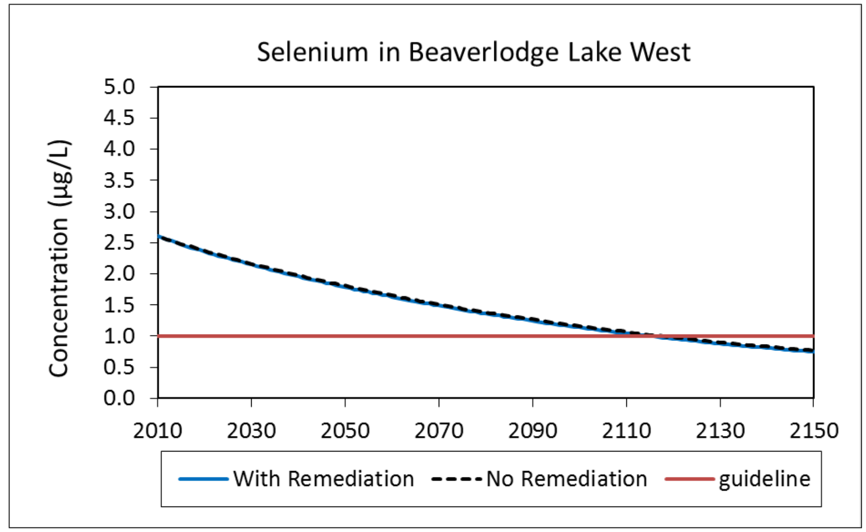


Figure 2.7-4 Beaverlodge Lake, West Segment Water Quality Predictions (Cover Fulton and Ace Bay Sediments)





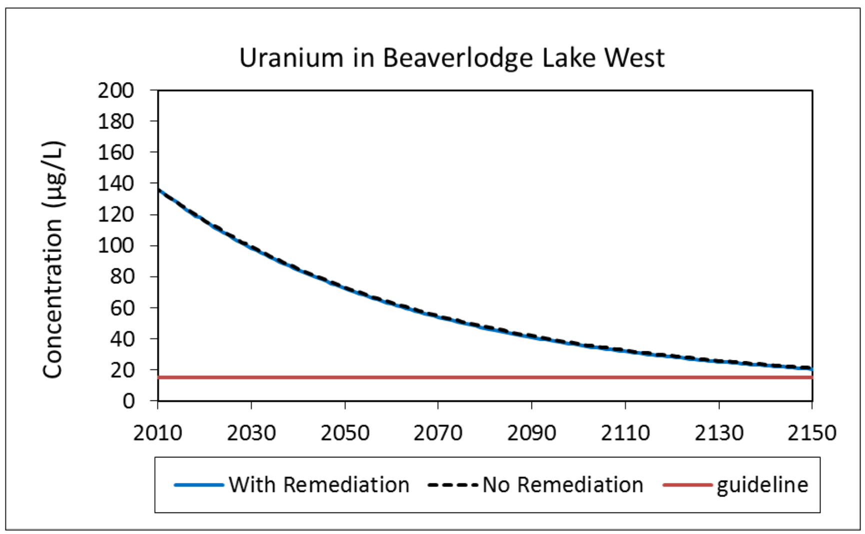


Figure 2.7-5 Summary of Outcomes in Fulton Bay, Beaverlodge Lake (Cover Fulton and Ace Bay Sediments)

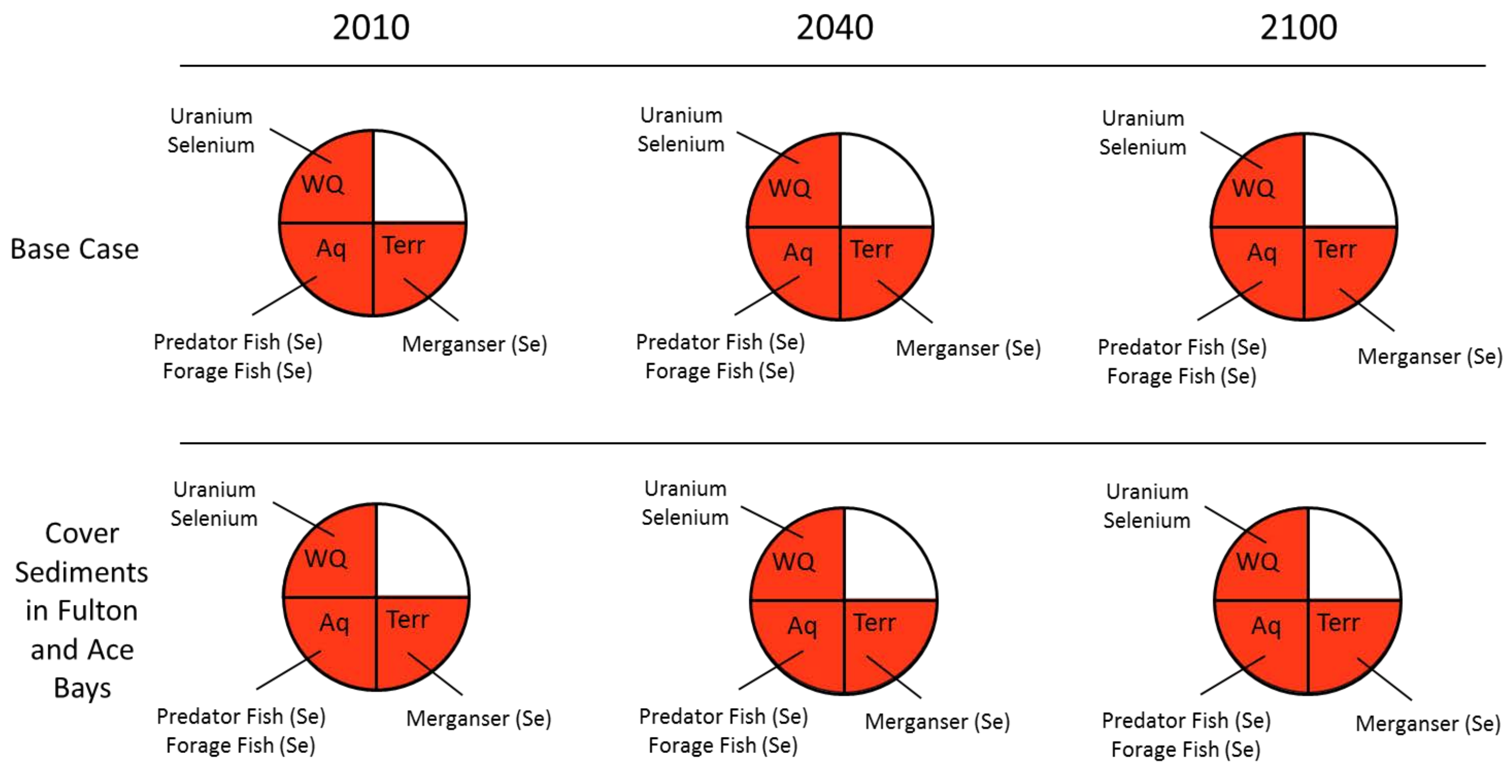


Figure 2.7-6 Summary of Outcomes in Ace Bay, Beaverlodge Lake (Cover Fulton and Ace Bay Sediments)

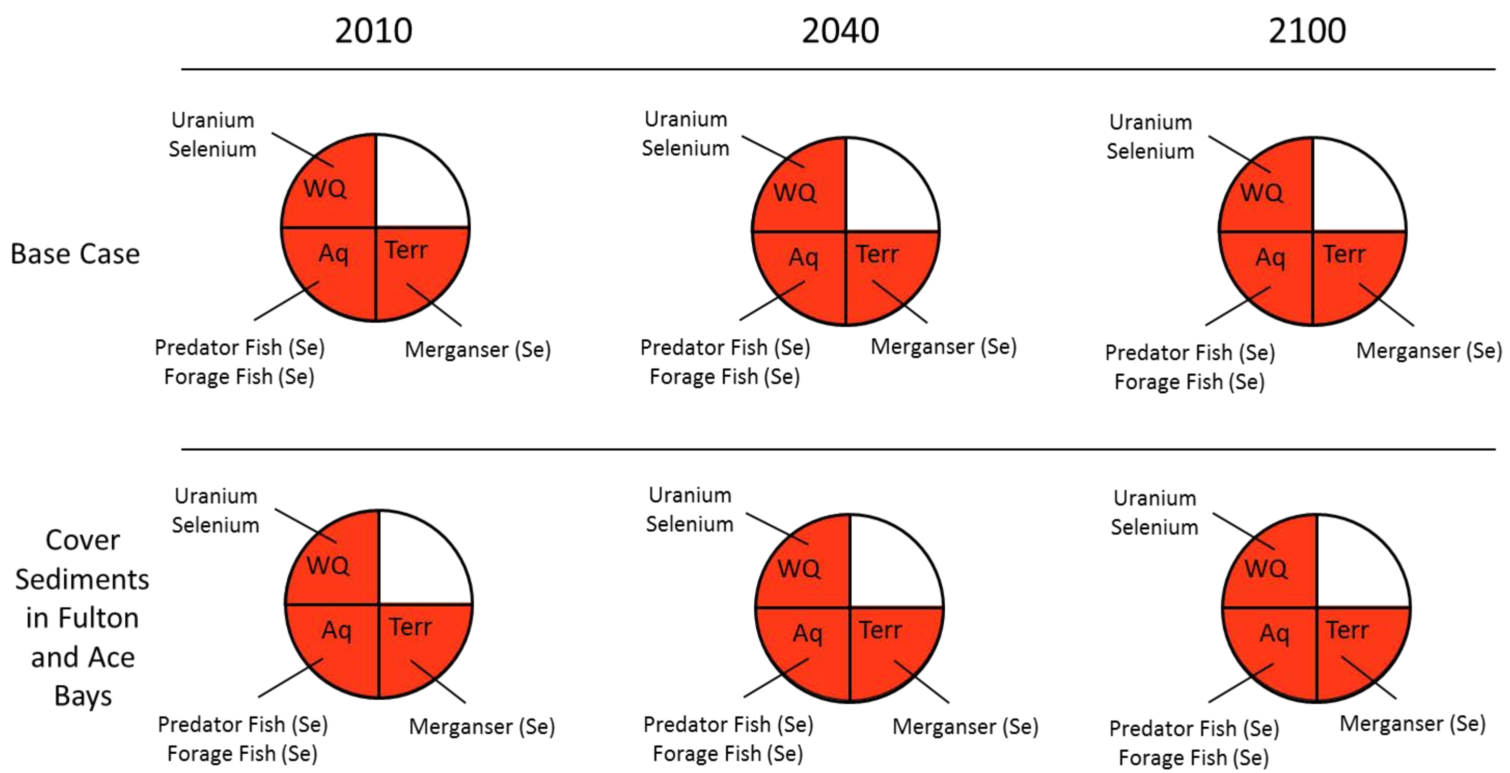
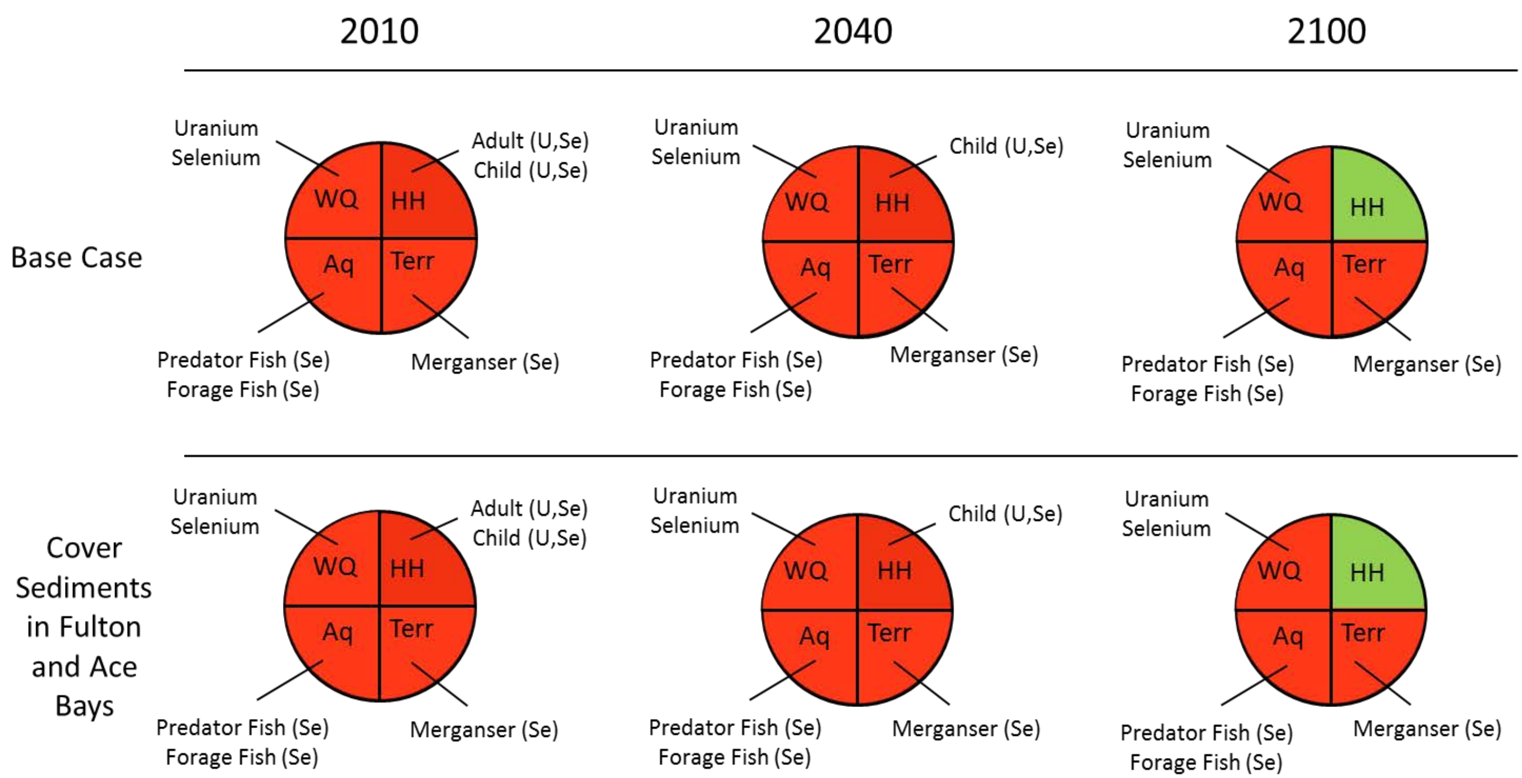


Figure 2.7-7 Summary of Outcomes in Beaverlodge Lake, West Segment (Cover Fulton and Ace Bay Sediments)



2.7.3.2 Induce Eutrophication and Associated Algal Blooms in Beaverlodge Lake

This is a potential remedial measure raised by a stakeholder during the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). The theory behind the activity is that inducing algal activity within Beaverlodge Lake would increase suspended solids for uranium and selenium to adsorb to and thus increase the amount of these constituents which are removed on settling material. It should be noted, however, that this method of artificially increasing productivity has only been attempted on a much smaller scale to date and that a significant amount of further research is required to better understand the potential risks and benefits of this type of whole lake manipulation.

Preliminary calculations were performed to estimate the amount of phosphorus which may be required to increase the sedimentation rate seen in Beaverlodge Lake by approximately 10 times. These rough calculations found that this increase in productivity would require addition of phosphate to equivalent of around 0.05 mg/L as P.

- The Potential change to environmental conditions based on increasing the sedimentation rate in Beaverlodge Lake by 10x was assessed using the Beaverlodge QSM (SENES 2012a) assuming the productivity (and sedimentation rate) is increased in the year 2015 and maintained throughout every year thereafter, for modeling purposes.

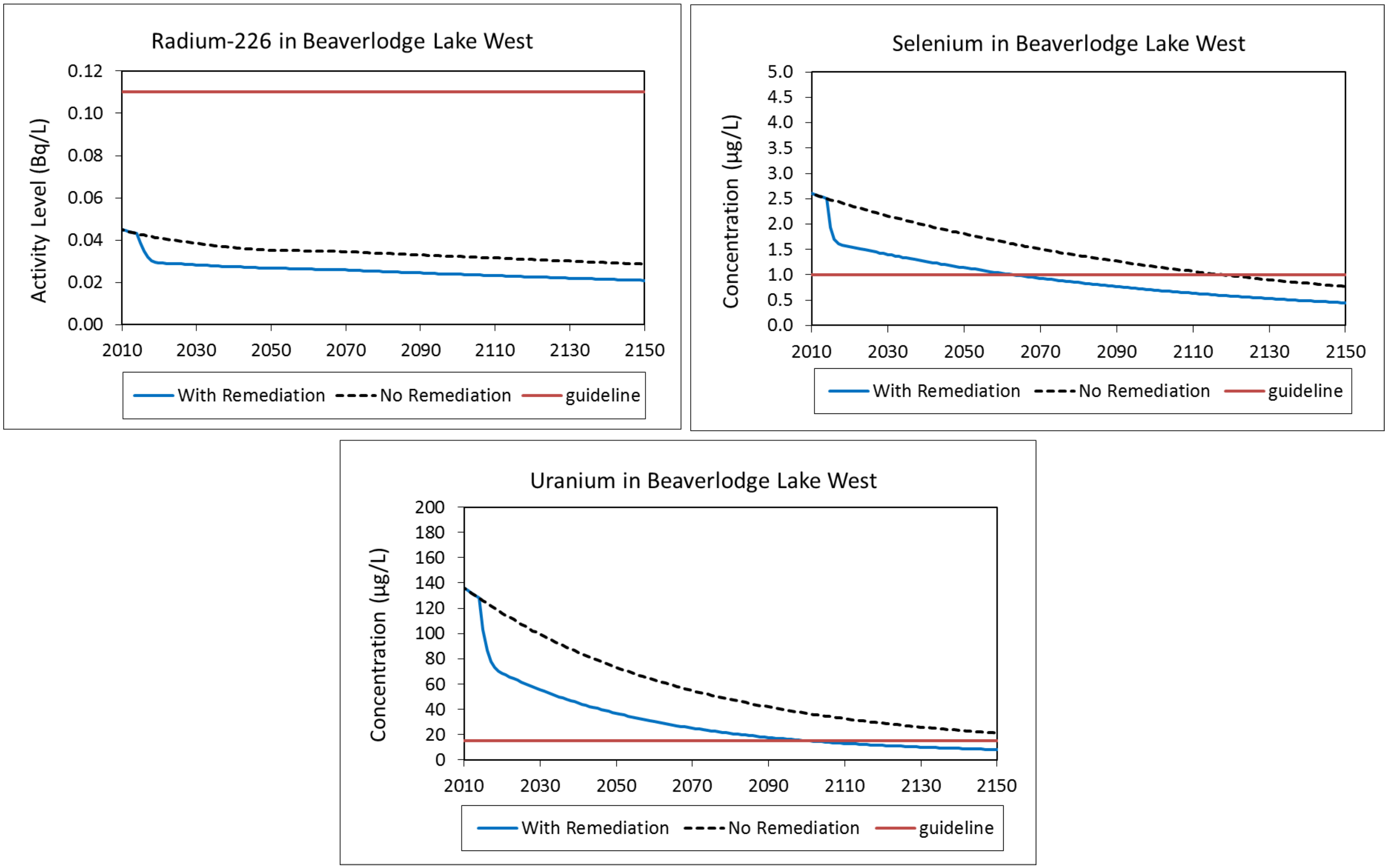
These assumptions result in a predicted reduction in radium-226 load of 25%, a reduction in uranium load of 45% and a reduction in selenium load of 35% to the downstream environment. It is important to note that, given the uncertainty regarding effectiveness of this remedial activity, the predicted benefit of this measure cannot be quantified with accuracy and that these predictions may be a great overestimate of the possible benefit.

The predicted water quality in the western region of Beaverlodge Lake is shown in Figure 2.7-8. As can be seen, this activity, although uncertain, may have the potential to significantly reduce water levels of selected contaminants. It should be noted that this measure involves removing contaminants to the sediments and if this elevated sedimentation rate is not maintained, water quality would suffer as there would be significant flux from the sediments back into the water column. Eutrophication of Beaverlodge Lake may have a highly negative impact on the existing ecosystem within Beaverlodge Lake; possible effects include change to species composition and anoxic conditions within the water column caused by increased sediment oxygen demand. It should be noted that these impacts may be seen in the downstream environment as well.

Costs of applying this amount of phosphate were very roughly estimated by ASKI, SENES & SRK (2012) to be approximately $10 Million CAD. It should be noted that this cost does not include costs for the considerable amount of research which would be required prior to implementation or for phosphate addition in perpetuity.

Stakeholders raised the point, during the 2012 Beaverlodge Remedial Options Workshop (ASKI, SENES & SRK 2012), that after further research to better understand the risks and benefits of inducing lake eutrophication with phosphate addition, application of this technology within the Beaverlodge study area on a smaller scale (ex. within Fookes Reservoir) may be considered a testing ground for this lake manipulation technique.

Figure 2.7-8 Beaverlodge Lake, West Segment Water Quality Predictions (Induce Algal Growth in Beaverlodge Lake)



2.7.4 Beaverlodge Lake Area Selection of Remedial Activities

In addition to predicted changes to the environment as assessed by the Beaverlodge QSM (SENES 2012a) and estimated costs of assessed activities (SENES & SRK 2012), opinions expressed during the Beaverlodge Remedial Option Workshop (ASKI, SENES & SRK 2012) can be used as additional information to help inform the remedial activity evaluation process. Outcomes from these three sources are discussed below. In addition, the costs and benefits for both of the remedial measures considered for the Beaverlodge Lake are summarized in Table 2.7-2. For each remedial activity expected change to exceedances, predicted reduction in loads, estimated costs as well as calculated cost per unit reduction are presented.

Table 2.7-2 Summary of Predicted Effects of Remedial Activities, Beaverlodge Lake Area

Remedial Measure	Change to Water Quality or Human/Eco Risk?[a]	Reduction in Load to Downstream Environment[b]			Estimated Costs (CAD)	Cost per Unit Reduction[b]			Comments
		Ra-226 (MBq/yr)	Se (kg/yr)	U (kg/yr)		Ra-226 (CAD/kBq/yr)	Se (CAD/g/yr)	U (CAD/g/yr)	
Cover sediments within Fulton and Ace bays of Beaverlodge Lake	slight decrease to merganser in Fulton Bay	402 (3%)	0.6 (1%)	22.2 (1%)	$29,300,000	730	53,000	1,320	-predicted effect on contaminant loads to Beaverlodge Lake and downstream minimal
Induce algal blooms in Beaverlodge Lake	not evaluated	299 (25%)*	22.7 (35%)*	1,265 (45%) *	$10,000,000 plus cost of lengthy research process and costs of reapplication in future years	33+*	440+*	8+*	-impacts and costs uncertain -likely difficult to obtain government approval for lake manipulation on this scale -further research scale work is required before employing these methods in a lake of this magnitude - stakeholder concern with eutrophication of a lake and impacts to downstream water

Notes:

[a] human receptors assessed at Beaverlodge Lake west segment but not Ace or Fulton bays of Beaverlodge Lake

[b] load reductions estimated over the first 50 years after implementation

* Actual benefits and associated costs per unit reduction may vary greatly from these values due to the uncertainty regarding effectiveness of implementing this remedial activity

Covering sediments within Fulton and Ace bays of Beaverlodge Lake is predicted to have very little impact on the water quality within Beaverlodge Lake. As mentioned previously, this result is due to the fact that these covers isolate only a very small fraction of the total impacted sediments within Beaverlodge Lake. This activity was discussed at the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012). During discussions stakeholders generally agreed that this measure is complex, costly and provides little benefit to the environment. It was also noted that these sediment covers would require a large amount of borrow material which is not readily available.

The idea of inducing algal growth within Beaverlodge Lake was discussed during the Beaverlodge 2012 Remedial Options Workshop (ASKI, SENES & SRK 2012) as well. The general conclusion reached by the stakeholders in attendance is that the measure would be attractive if the long-term safety and effectiveness could be proven. Concerns raised included the potential for negative side effects such as localized and downstream hypoxia resulting from eutrophication; chronic impacts on lake ecology and habitat; and potential for acute harm to aquatic wildlife during phosphorus application. In addition to these identified draw backs, it would also be a difficult task to obtain regulatory approval for lake manipulation of this scale.

Based on the evaluation presented above, the recommended course of action developed by Cameco for the Beaverlodge Lake area is monitored natural attenuation to ensure recovery is progressing as expected. The considered remedial activities are not recommended due to the fact that little benefit is predicted for Beaverlodge Lake as a result of applying sediment covers and the activity cannot be justified under the Management Framework. In addition, there is technical uncertainty and stakeholder concern around the idea of inducing algal blooms.

3.0 BEAVERLODGE REMEDIAL PATH FORWARD

A remedial path forward was developed by Cameco, in consultation with Canada Eldor based on the analysis presented in Chapter 2. This remedial action plan includes some site-specific activities as well as a number of site-wide activities. Remedial activities incorporated include measures which are predicted to improve conditions in the aquatic environment and, other measures which are considered to be good engineering practice and/or would improve safety of human and ecological receptors that may access the site. All selected remedial activities are considered to be justified under the Beaverlodge Management Framework.

In addition to those measures evaluated in Chapter 2, the Beaverlodge Path Forward plan includes continued monitoring of water quality at well-established monitoring stations throughout the Beaverlodge study area as well as the development and implementation of a regional monitoring program aimed at monitoring recovery in Beaverlodge Lake and the downstream environment. This regional monitoring program is a joint program being developed with Saskatchewan Research Council, as the manager of the CLEANS project responsible for the remediation the nearby Gunnar and Lorado mine and mill sites. The regional monitoring program is currently under development and will be reviewed with regulatory agencies and stakeholders prior to implementation. Once implemented, it is envisioned that this monitoring program will form the basis for continued long-term monitoring by the Province of Saskatchewan after the Beaverlodge study area properties have been transferred to the IC program.

Prior to release to the IC program, all waste rock and tailings areas within the Beaverlodge study area will undergo a detailed gamma survey and easily accessible areas with elevated gamma fields will be covered with sand to reduce emissions to meet ALARA (social and economic factors considered).

Selected site-specific activities include:

- Divert Zora Creek around the Bolger waste rock pile

Activities selected for the Beaverlodge remedial plan which apply site-wide include:

- Plug all identified flowing and non-flowing boreholes to prevent potential groundwater outflow in the future.

- Replace caps on all vertical mine openings to improve long-term safety.

- Perform gamma survey of all waste rock and tailings areas and cover easily accessible areas with elevated gamma fields to reduce gamma to meet ALARA (social and economic factors considered).

- Continue monitoring water quality throughout the Beaverlodge study area to monitor future trends.

- Develop regional long-term monitoring program.

4.0 PERFORMANCE OBJECTIVES

Water quality within many of the modeled water bodies is expected to remain above Saskatchewan Surface Water Quality Objectives (SSWQO) for many years despite implementation of the remedial plan proposed herein; however, the human and ecological risks have been assessed as presented in this report and are being managed in accordance with the Beaverlodge Management Framework to acceptable levels.

In this chapter a set of site specific performance objectives are derived for the Beaverlodge study area as a means to assess the success of implementing the selected remedial action plan presented in Chapter 3. The performance objectives serve two purposes; first, they will be used in the short term (i.e., 5 years) as a site specific target to assess the remedial activities that are implemented; secondly, they will be used after the properties have been transferred to the IC program to compare long-term recovery of the properties and the downstream environment to predictions.

In accordance with the Beaverlodge Management Framework, short-term performance objectives will be used to evaluate the success of those remedial options being implemented. Once short term performance objectives are achieved, they will form the basis for transferring the sites to the IC program. If short-term performance objectives are not achieved, then residual risks will be assessed as per the Beaverlodge Management Framework presented in Chapter 1. Long-term performance objectives provide the expected recovery that will be monitored by the Province of Saskatchewan as part of IC.

Performance objectives were derived based on water column concentrations as impacts of the sites are most easily measured within the water column and there is currently an ongoing water quality monitoring program in place at well-established stations throughout the Beaverlodge study area (as shown previously in Figure 1.2-3).

In order to develop site-specific performance objectives, the effects of uncertainty in key parameters in the Beaverlodge Quantitative Site Model (QSM) on water quality predictions were examined to establish bounds on the predictions; these bounds were then used as the basis for determining reasonable site-specific water quality objectives.

4.1 DERIVATION OF WATER QUALITY PREDICTION BOUNDS

In order to determine a reasonable range for water quality predictions within Beaverlodge study area water bodies, the parameters in the QSM were first assessed to determine which parameters have the greatest effect on the model outcomes. Parameter identifiability analysis completed as part of previous work (Hamer *et al*. 2012) has shown that the three parameters within the Beaverlodge QSM that have the largest impact on predicted water quality are:

External Load (L)	- defined as all loads other than those loads originating from within the modeled lakes
K_1 (K)	- defined as the mass transport coefficient between sediment porewater and the water column
Flow/Precipitation (P)	- defined as flow through the system as driven by precipitation rates; as determined from watershed flow data

Uncertainty bounds in these model input parameters were set at two standard deviations about the mean (expected) values as follows:

Define ^{-}P as P_{mean} – 1.96 * Standard Deviation of P
^{+}P as P_{mean} + 1.96 * Standard Deviation of P
Similarly ^{-}K, ^{+}K, ^{-}L and ^{+}L can be defined the same manner

To determine upper and lower bounds on precipitation based flow, average annual flows measured at AC-8 between 1983 and 2010 were examined. The standard deviation for the annual average flow was calculated and the 5^{th} and 95^{th} percentile flows determined. These values were then converted to a unit area runoff for the region which was applied to the entire site for appropriate runs.

To determine upper and lower bounds for External Loads, the distributions for L_1 and L_2 obtained through the Metropolis Hastings procedure during calibration of the external source load model for each site (Chapter 5, SENES 2012a) were examined for each of the external loads to the system. The standard deviations of these distributions were determined on a percentage basis. The median standard deviation was just under 15%, so standard deviation of all external loads was taken to be 15% of the calibrated value.

Similarly for the mass transport coefficient (K_1), the K_1 distributions obtained through the Metropolis Hastings procedure during calibration (Chapter 5, SENES 2012a) were examined to determine the standard deviations. Again, the median standard deviation was between 10 and

15%, therefore, the standard deviation of all K_l values was taken to be 15% of the calibrated value.

Then, the following simulations were performed as in Factorial Analysis assuming the selected remedial measures were all implemented in the year 2015:

^{+}P ^{+}K ^{+}L
^{+}P ^{+}K ^{-}L
^{+}P ^{-}K ^{+}L
^{+}P ^{-}K ^{-}L
^{-}P ^{+}K ^{+}L
^{-}P ^{+}K ^{-}L
^{-}P ^{-}K ^{+}L
^{-}P ^{-}K ^{-}L

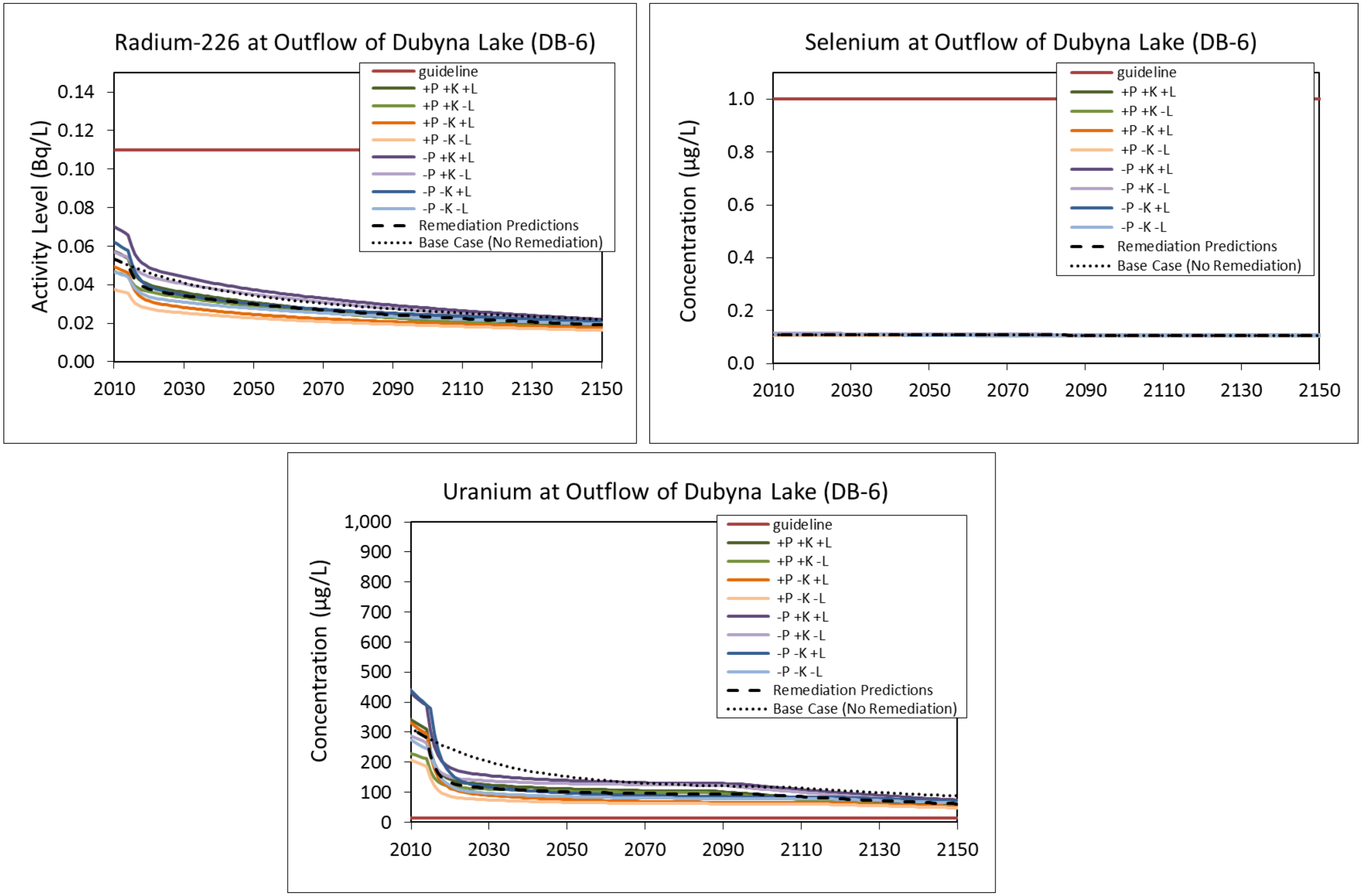
Altogether, ten simulations were carried out including the eight runs listed above, a run assessing selected remedial measures (Remediation Predictions) using calibrated values and the base case run with no remediation.

Selected remedial measures included in the remedial plan are which are expected to change water quality predictions are:

- Plug Dubyna Boreholes (assumed to stop 80% of flow from underground mine and thus reduce both the L_1 and L_2 components of the load from underground mine workings by 80%)
- Divert Zora Creek to avoid contact with waste rock (assumed to reduce the loading from the Bolger/Verna waste rock piles by re-routing Zora Creek flow around the Bolger waste rock pile; it is assumed that both the L_1 and L_2 components of the load from waste rock pile are reduced by 50%)

This process allows us to identify expected upper and lower bounds on predicted water quality throughout the simulated time period taking into account combinations of extreme (95^{th} and 5^{th} percentile) values for flows, mass transfer coefficients and external loads assuming all selected remedial activities are completed by the year 2015. Predicted water column concentrations assuming these combinations of extreme values are shown in Figure 4.1-1 for Dubyna Lake as an example case. The eight runs performed using permutations of extreme values are plotted along with the base case prediction assuming implementation of no remedial measures, the base remedial measure predictions and the applicable guideline for comparison. The range of predictions encompassed by these eight Factorial Analysis simulation runs is expected to serve as reasonable bounds on the water quality predictions assuming implementation of the selected remedial plan.

Figure 4.1-1 Example Water Quality Prediction Range, Dubyna Lake



The process of applying combinations of extreme values for flow, mass transport coefficient and external load was completed for each studied water body and the resulting range seen in the eight Factorial Analysis runs was distilled into two curves; maximum and minimum values at each time point from these eight runs. The derived maximum and minimum water column predictions are presented below, in Figures 4.1-2 to 4.1-13, along with predictions for the base case with no remediation, base predictions assuming implementation of the selected remedial plan and the applicable guideline.

The bounds presented in Figures 4.1-2 to 4.1-13 can be used in future years to assess whether annual measured water column concentrations within these water bodies are following predicted trends as a general assessment of model adequacy. It is important to note that these predictions are for yearly averages; it is not expected that every individual measurement will fall within these bounds.

It should be noted that selenium predictions are not included for water bodies within the Ace Creek Watershed as these levels are currently well below the applicable surface water quality guideline and predicted to remain there throughout the modeled time period.

In cases where the upper and/or lower bounds on water column predictions fall above the applicable water quality guideline (shown as solid lines in Figures 4.1-2 to 4.1-13), they were used as a basis for setting site-specific performance objectives based on implementation of the selected path forward as presented in Chapter 3. Further discussion of the resulting performance is provided in the following section. The water quality predictions which fall below the SSWQO are shown as dashed light and dark blue lines; these predictions are included to assess model accuracy in the future and will not trigger reassessment of remedial options.

Figure 4.1-2 Bounding Water Quality Predictions, Dubyna Lake

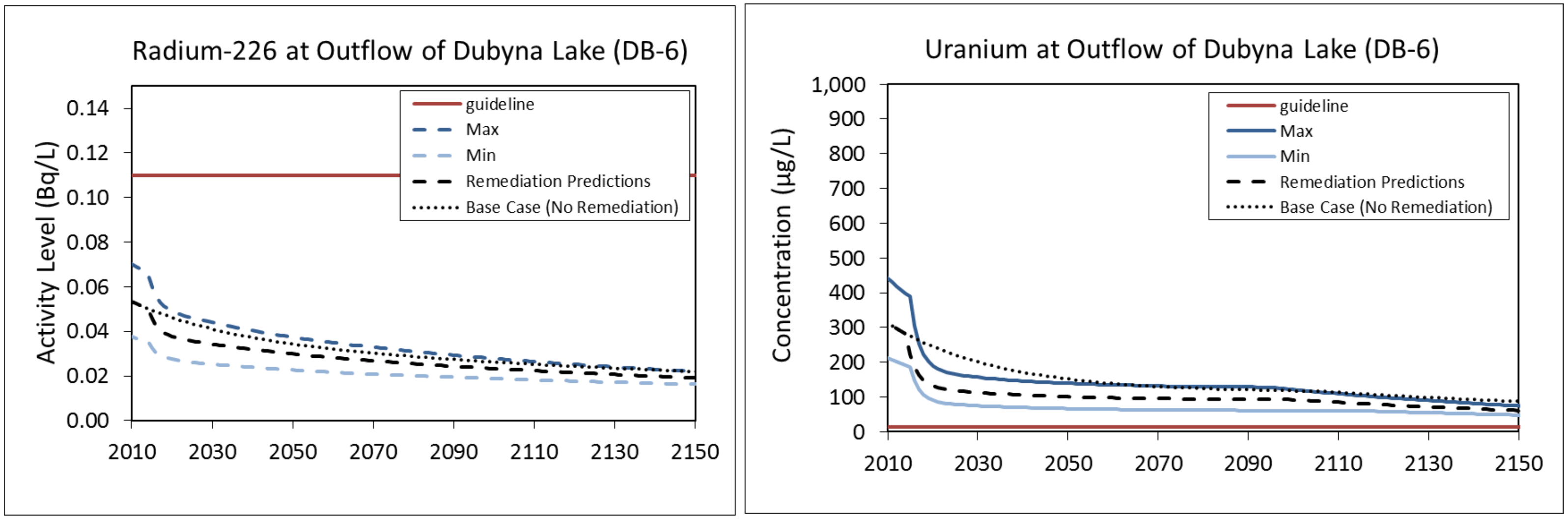


Figure 4.1-3 Bounding Water Quality Predictions, Pistol Lake

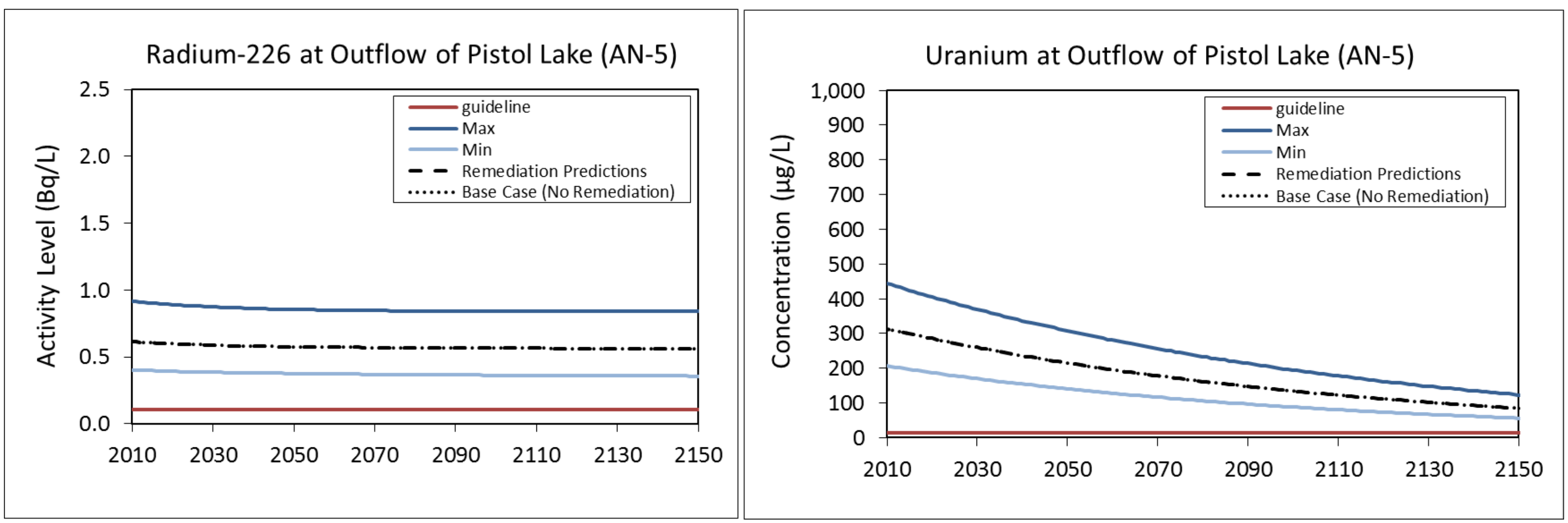


Figure 4.1-4 Bounding Water Quality Predictions, Verna Lake

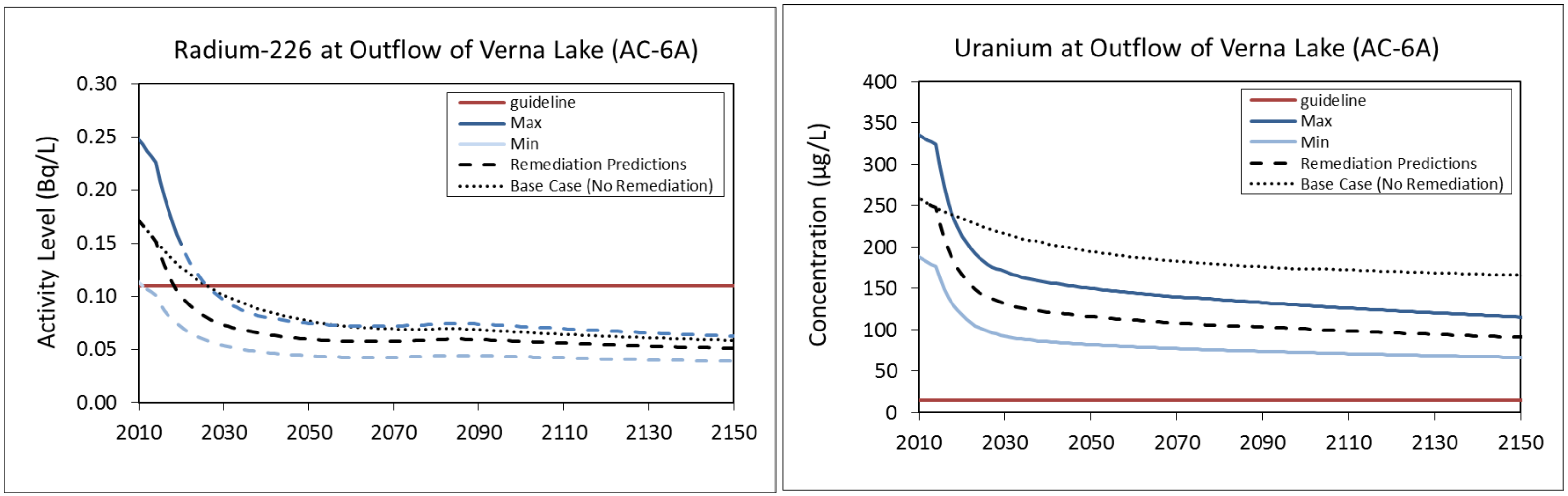


Figure 4.1-5 Bounding Water Quality Predictions, Ace Lake

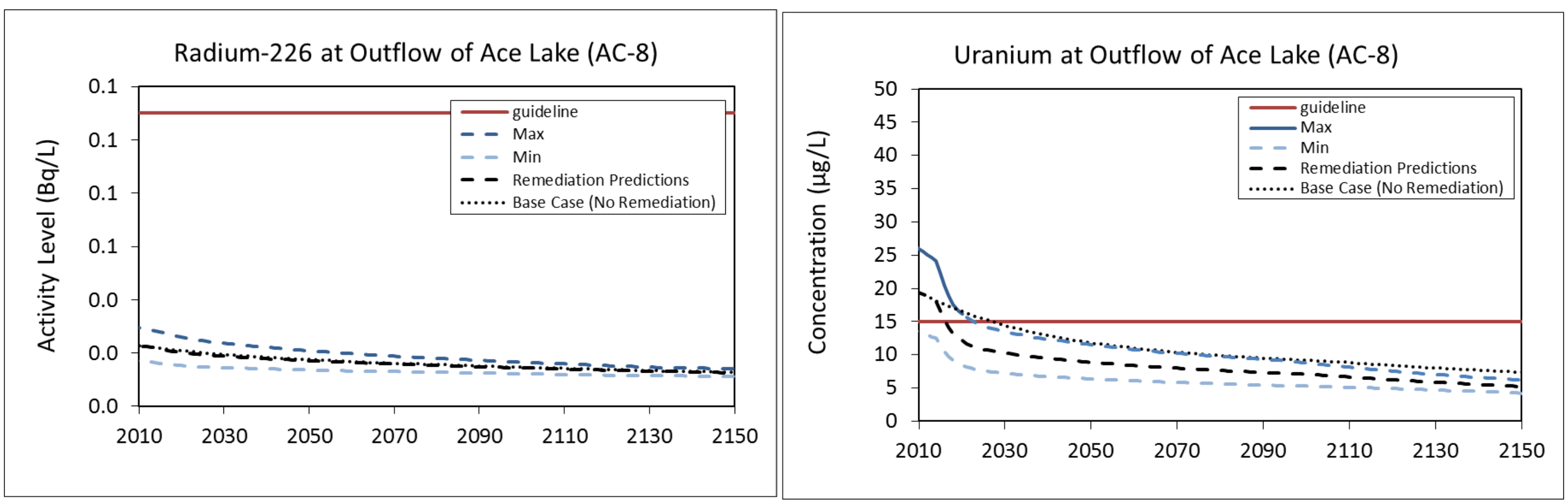


Figure 4.1-6 Bounding Water Quality Predictions, Lower Ace Creek

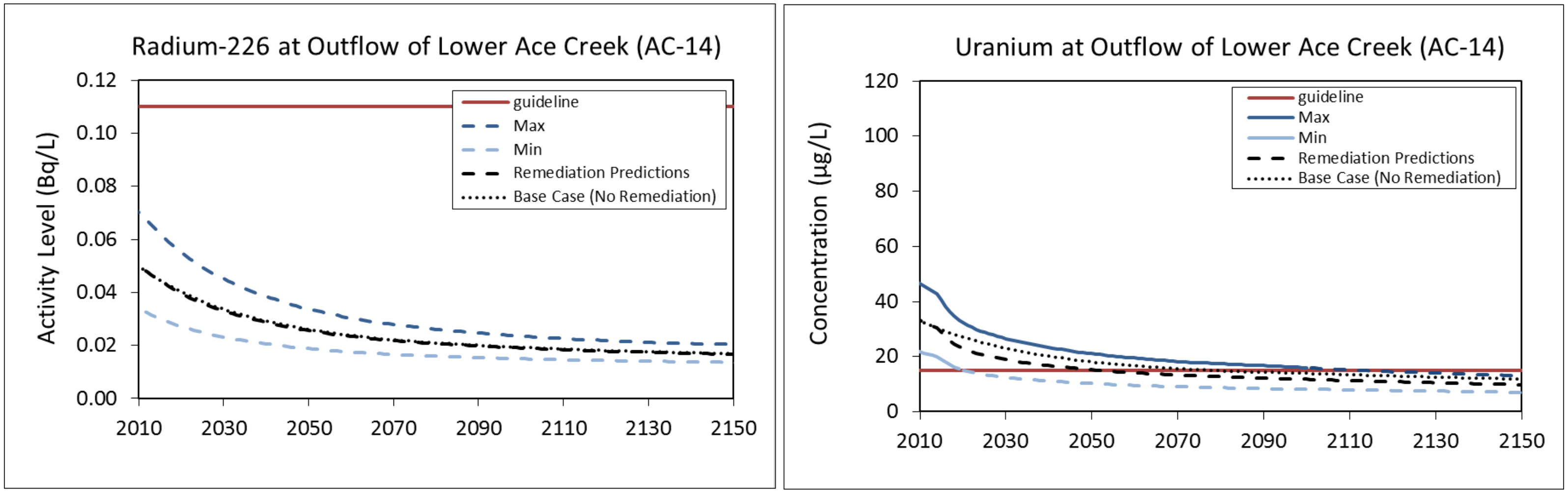


Figure 4.1-7 Bounding Water Quality Predictions, Fookes Reservoir

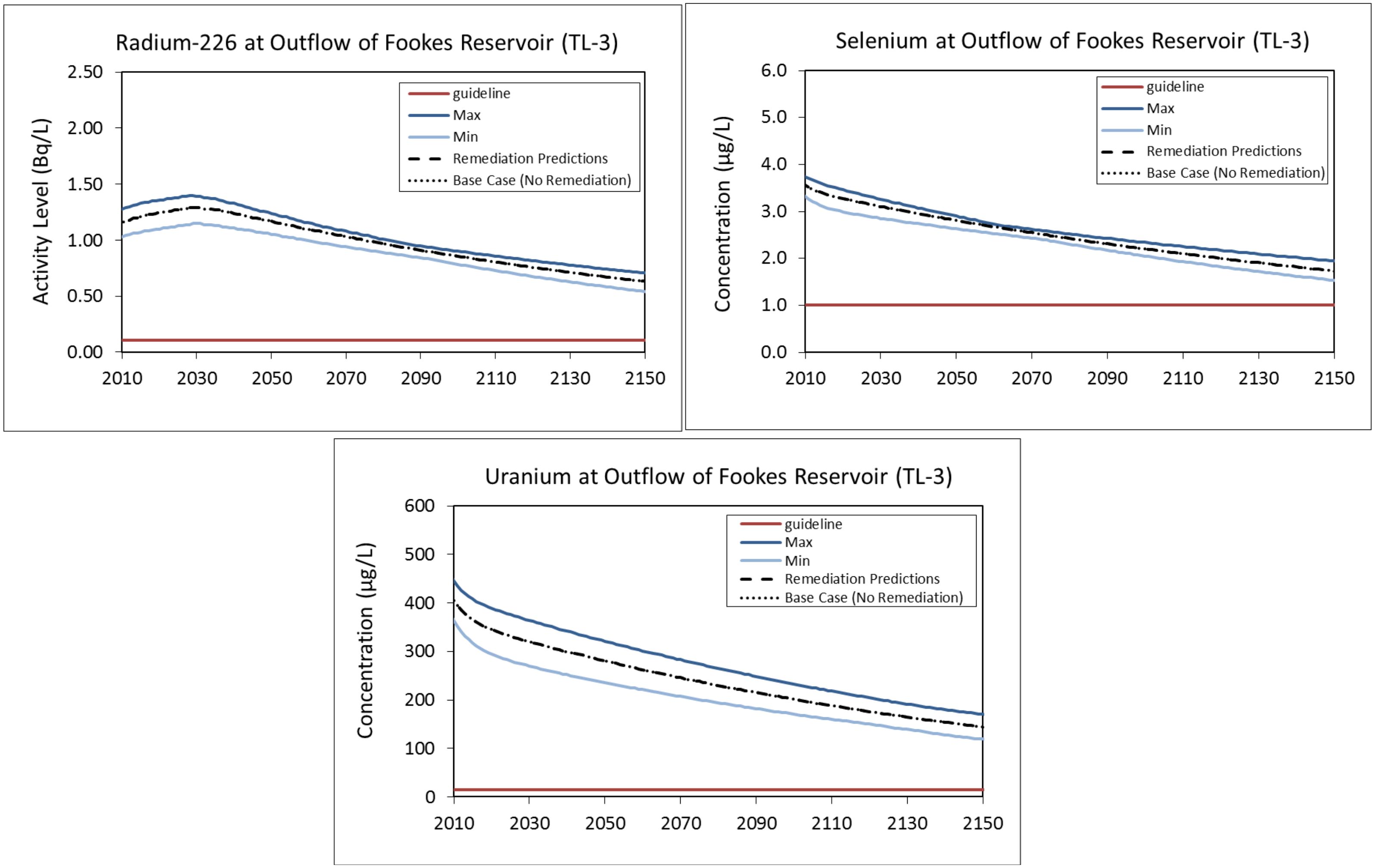


Figure 4.1-8 Bounding Water Quality Predictions, Marie Reservoir

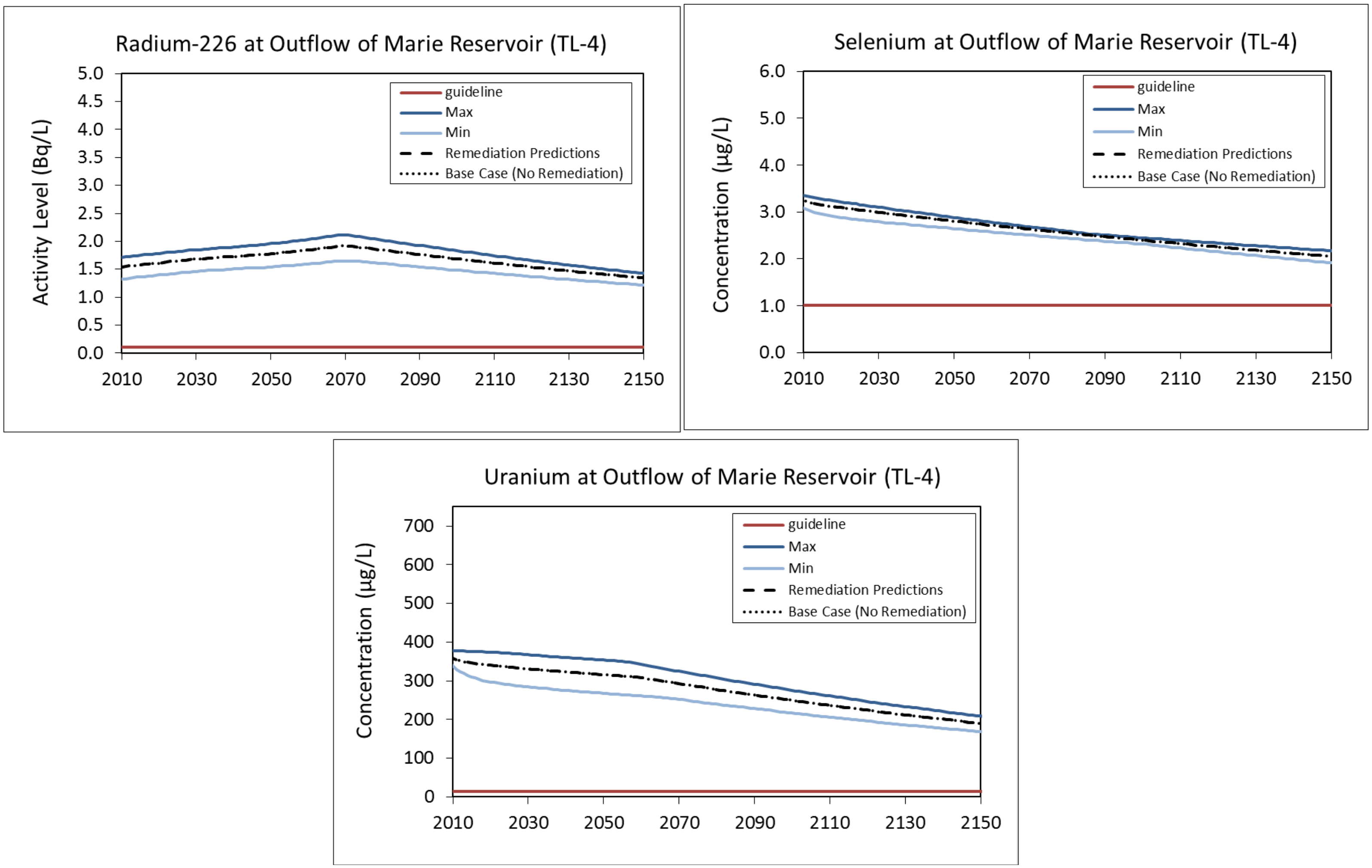


Figure 4.1-9 Bounding Water Quality Predictions, Meadow Fen

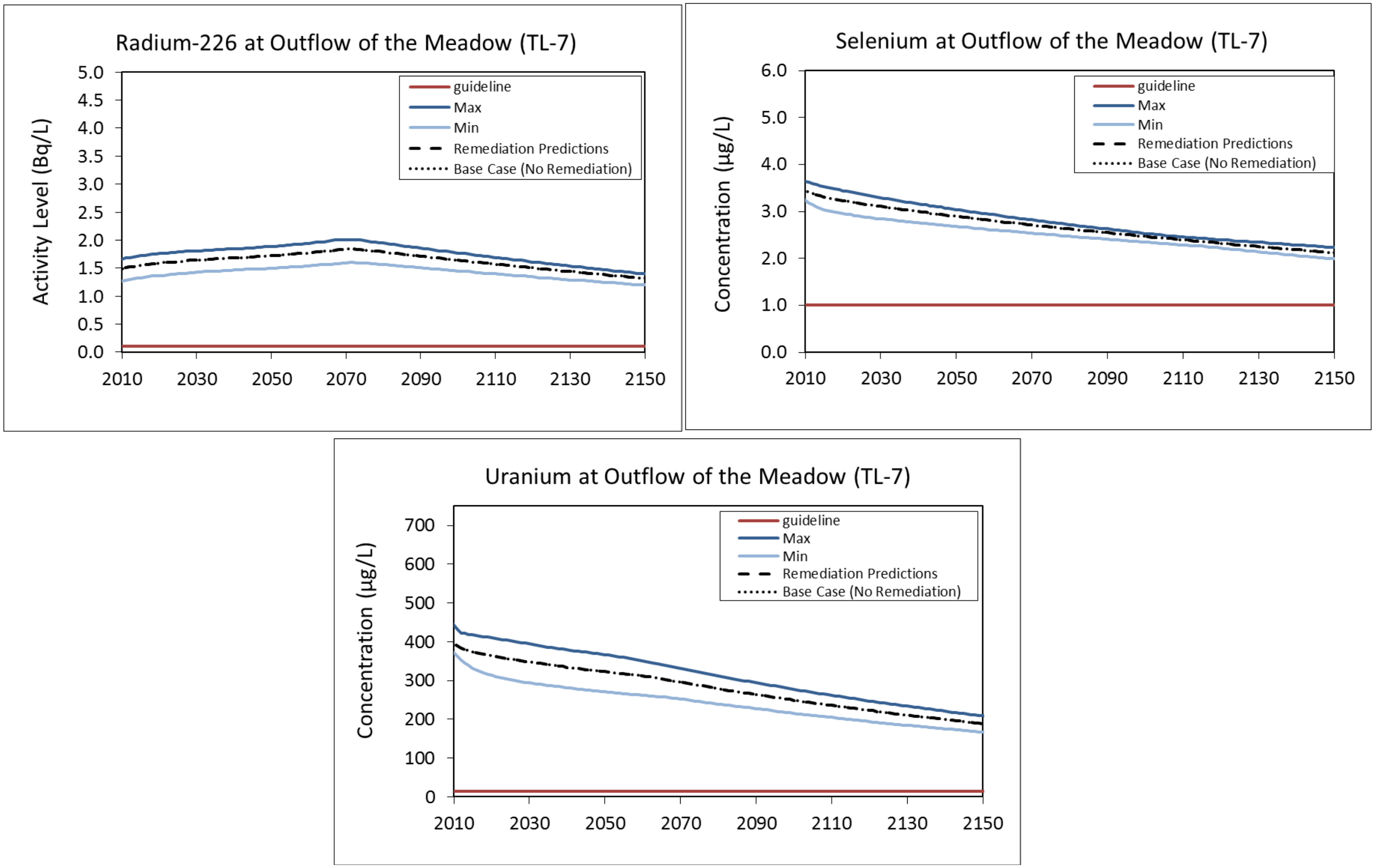


Figure 4.1-10 Bounding Water Quality Predictions, Greer Lake

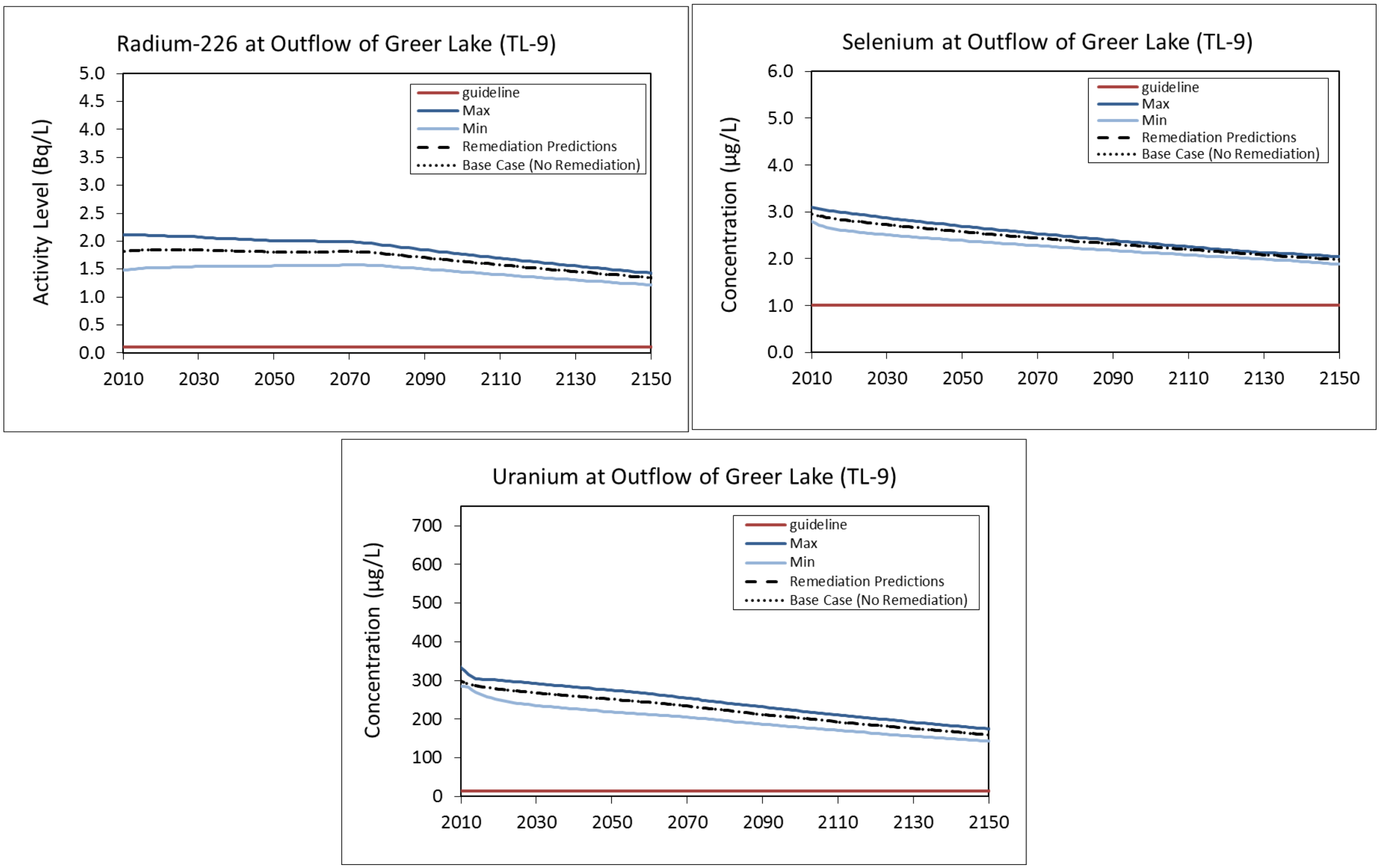


Figure 4.1-11 Bounding Water Quality Predictions, Ace Bay of Beaverlodge Lake

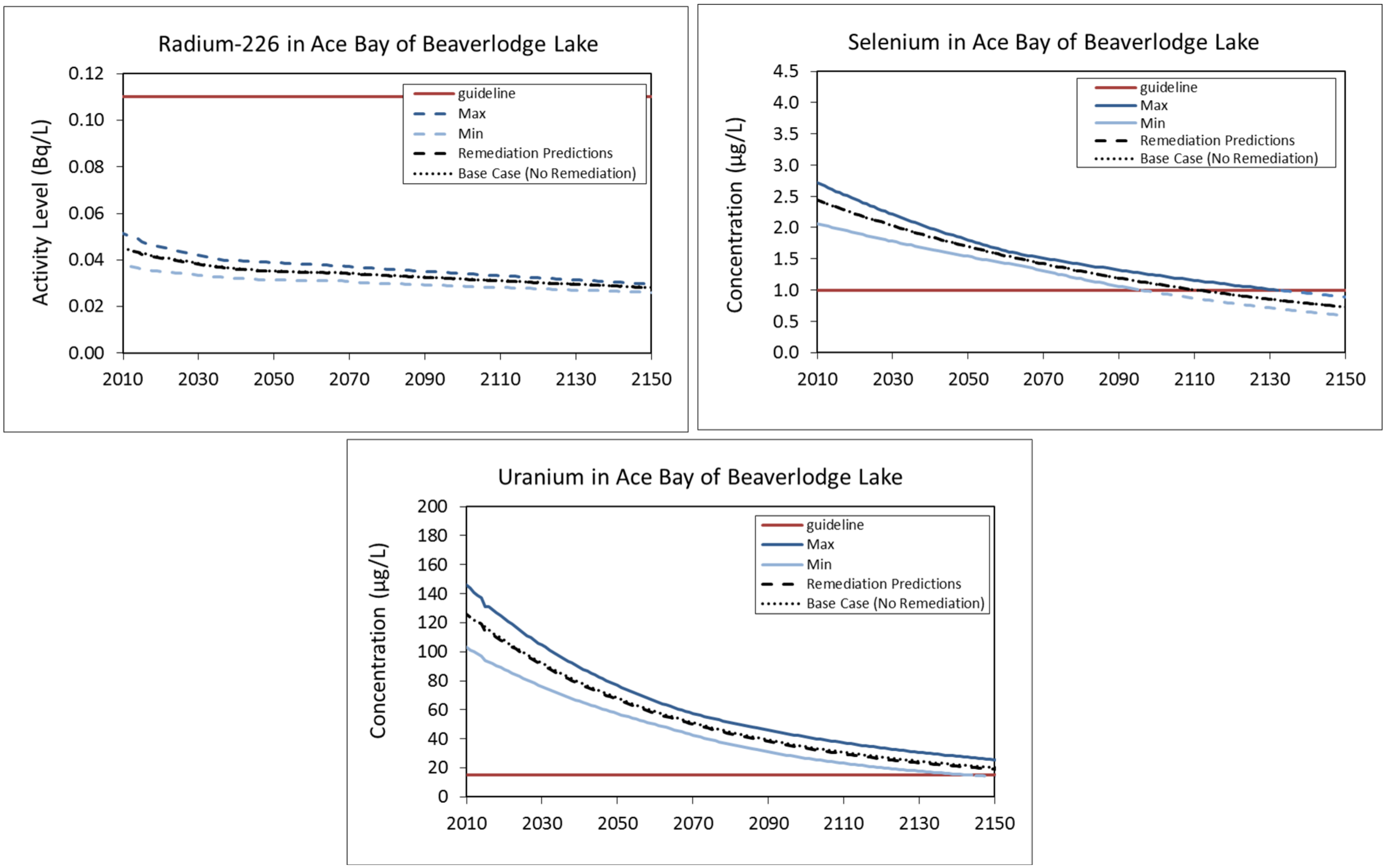


Figure 4.1-12 Bounding Water Quality Predictions, Fulton Bay of Beaverlodge Lake

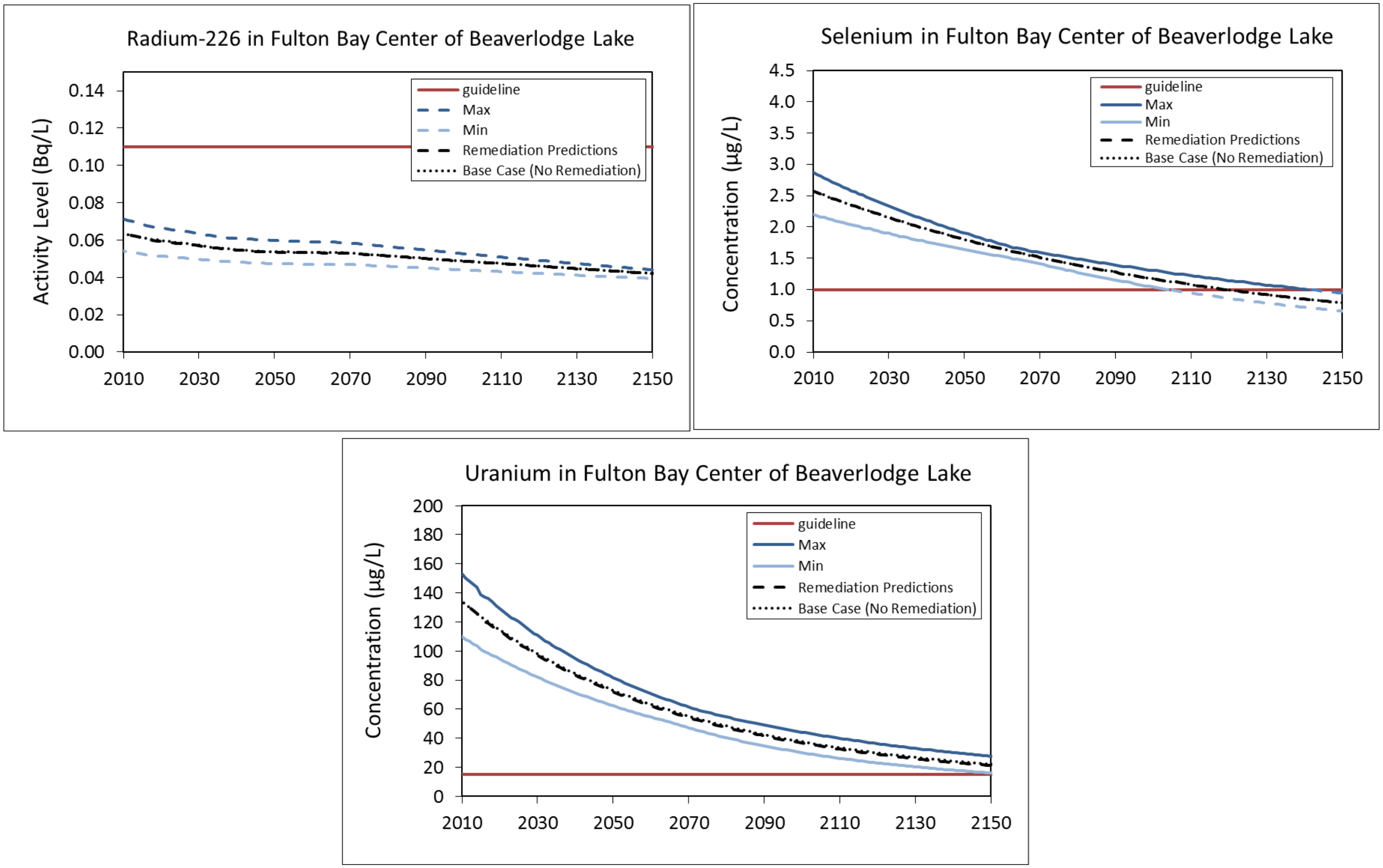
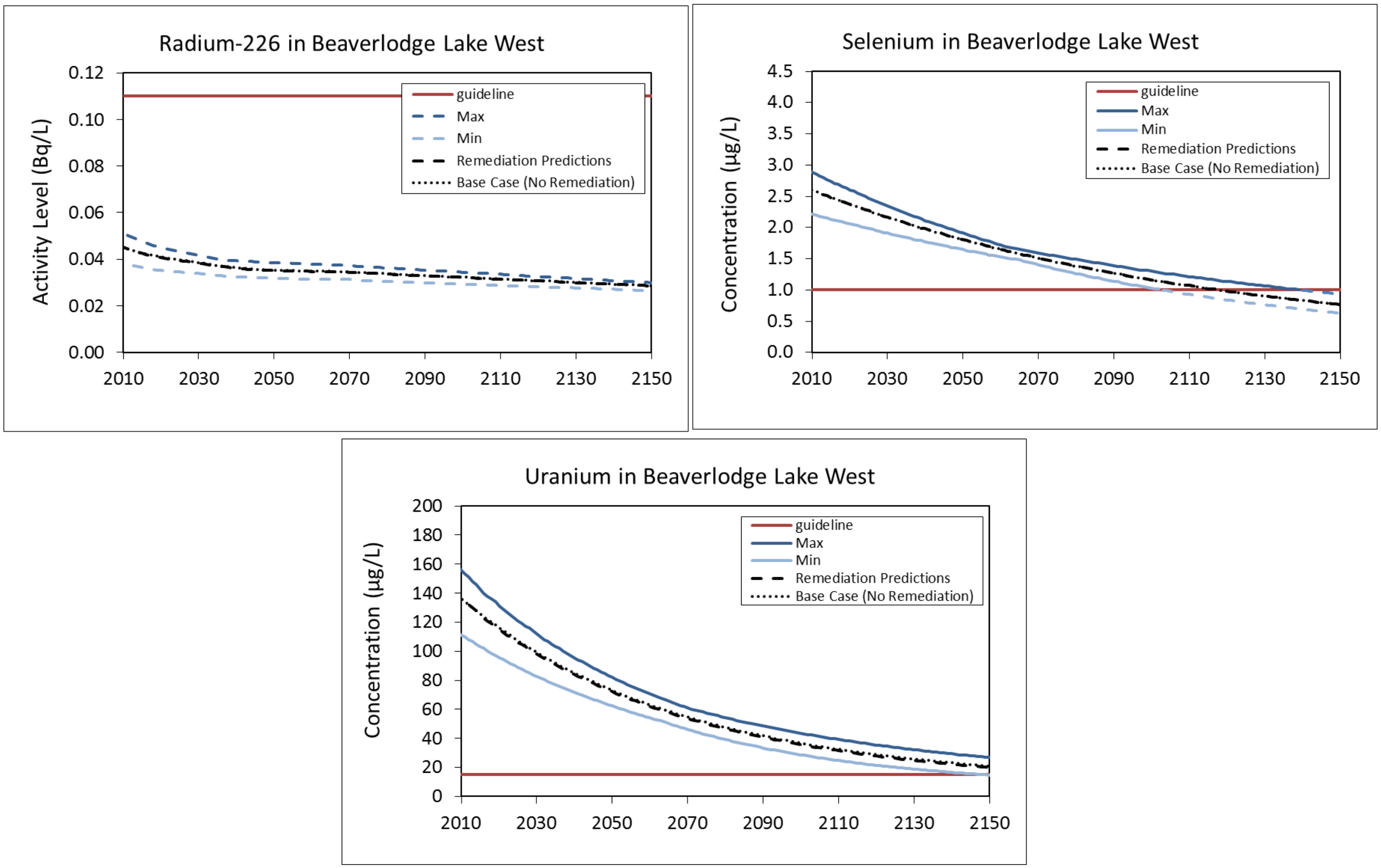


Figure 4.1-13 Bounding Water Quality Predictions, Beaverlodge Lake



4.2 BEAVERLODGE SITE SPECIFIC PERFORMANCE OBJECTIVES

The performance objectives presented in this section were derived to provide a method to assess trends in surface water quality over time against the predictions in this report. The site specific performance objectives have a short-term and long-term component, with the short-term component intended to evaluate the success of implementing a site specific remedial option, while the long-term component provides the expected recovery to be monitored following the properties transfer to IC.

Beaverlodge study area site-specific performance objectives were derived in the following way. If the upper bound on predictions was above the applicable surface water quality guideline (shown in Figures 4.1-2 to 4.1-13 as dark blue solid lines), the upper bound value was selected as the performance objective while if it was below the criterion, the surface water objective was taken as the performance objective. Lower bounds on predicted water column concentrations are presented to allow for the assessment of model adequacy.

Upper and lower performance objectives for selected years are shown in Tables 4.2-1, 4.2-2 and 4.2-3 for radium-226, selenium and uranium, respectively. These performance objectives apply only to general trends within these water bodies; it is not expected that all individual measurements will fall within this range. It should be noted that these model predictions, and associated performance objectives, do not attempt to predict the short term negative impacts which may result from disturbing the Bolger waste rock pile to implement the Zora Creek stream diversion.

Table 4.2-1 Annual Water Quality Performance Objectives, Radium-226

Water Body	Radium-226 Concentration (Bq/L)					
	2020		2050		2100	
	Upper	Lower	Upper	Lower	Upper	Lower
Dubyna Lake	0.11	-	0.11	-	0.11	-
Pistol Lake	**0.89**	**0.39**	**0.86**	**0.38**	**0.84**	**0.36**
Verna Lake	**0.15**	-	0.11	-	0.11	-
Ace Lake	0.11	-	0.11	-	0.11	-
Lower Ace Creek	0.11	-	0.11	-	0.11	-
Fookes Reservoir	**1.36**	**1.10**	**1.24**	**1.05**	**0.90**	**0.79**
Marie Reservoir	**1.78**	**1.40**	**1.96**	**1.54**	**1.83**	**1.48**
The Meadow	**1.76**	**1.37**	**1.89**	**1.50**	**1.77**	**1.45**
Greer Lake	**2.10**	**1.53**	**2.01**	**1.56**	**1.77**	**1.45**
Ace Bay, Beaverlodge Lake	0.11	-	0.11	-	0.11	-
Fulton Bay, Beaverlodge Lake	0.11	-	0.11	-	0.11	-
Beaverlodge Lake	0.11	-	0.11	-	0.11	-

Table 4.2-2 Annual Water Quality Performance Objectives, Selenium

Water Body	Selenium Concentration (ug/L)					
	2020		2050		2100	
	Upper	Lower	Upper	Lower	Upper	Lower
Dubyna Lake	1	-	1	-	1	-
Pistol Lake	1	-	1	-	1	-
Verna Lake	1	-	1	-	1	-
Ace Lake	1	-	1	-	1	-
Lower Ace Creek	1	-	1	-	1	-
Fookes Reservoir	**3.46**	**2.99**	**2.90**	**2.63**	**2.34**	**2.05**
Marie Reservoir	**3.21**	**2.88**	**2.88**	**2.64**	**2.45**	**2.31**
The Meadow	**3.44**	**2.95**	**3.04**	**2.68**	**2.53**	**2.34**
Greer Lake	**2.97**	**2.59**	**2.69**	**2.39**	**2.32**	**2.13**
Ace Bay, Beaverlodge Lake	**2.45**	**1.92**	**1.80**	**1.54**	**1.23**	-
Fulton Bay, Beaverlodge Lake	**2.58**	**2.04**	**1.91**	**1.64**	**1.30**	**1.04**
Beaverlodge Lake	**2.60**	**2.06**	**1.91**	**1.65**	**1.30**	**1.03**

Table 4.2-3 Annual Water Quality Performance Objectives, Uranium

Water Body	Uranium Concentration (ug/L)					
	2020		2050		2100	
	Upper	Lower	Upper	Lower	Upper	Lower
Dubyna Lake	**181**	**87**	**139**	**66**	**120**	**61**
Pistol Lake	**401**	**186**	**305**	**139**	**193**	**88**
Verna Lake	**213**	**118**	**150**	**82**	**129**	**72**
Ace Lake	**16**	-	15	-	15	-
Lower Ace Creek	**32**	-	**21**	-	**16**	-
Fookes Reservoir	**389**	**295**	**321**	**236**	**233**	**170**
Marie Reservoir	**374**	**297**	**354**	**268**	**276**	**217**
The Meadow	**410**	**313**	**366**	**271**	**277**	**216**
Greer Lake	**301**	**250**	**275**	**219**	**221**	**179**
Ace Bay, Beaverlodge Lake	**123**	**88**	**77**	**58**	**42**	**27**
Fulton Bay, Beaverlodge Lake	**130**	**95**	**82**	**63**	**45**	**30**
Beaverlodge Lake	**132**	**96**	**82**	**62**	**44**	**29**

5.0 CONCLUSIONS

The purpose of this report was to provide Cameco's path forward plan, which was developed in consultation with Canada Eldor, for remedial activities at the Beaverlodge mine site in northern Saskatchewan along with a discussion of the supporting information which was used to aid the decision making process. This remedial plan was developed using input from many studies including the Beaverlodge QSM (SENES 2012a), the Beaverlodge Costing Study (SENES & SRK 2012) and the 2012 Beaverlodge Remedial Options Workshop (ASKI, SENES & SRK 2012).

Remedial activities incorporated in the developed Beaverlodge remedial action plan are as follows:

- Divert Zora Creek around the Bolger waste rock pile.
- Plug all identified boreholes across the study area.
- Replace caps on all vertical mine openings across the study area.
- Perform gamma survey of all waste rock and tailings areas and cover easily accessible areas with elevated gamma fields.
- Continue monitoring water quality throughout the Beaverlodge study area.
- Develop regional long-term monitoring program.

This path forward plan provides clear direction regarding the implementation and expectations of performing remedial activities on the Beaverlodge properties to facilitate their transfer into the IC program. A number of the peripheral licensed sites will require little or no further remediation and we expect to apply for their release to the IC program within five years. It is anticipated those areas requiring additional remediation will be eligible for release to the ICP within a 10 year period following implementation of the proposed remedial actions followed by a period to evaluate the success of the activity as compared to the short term performance objectives.

REFERENCES

ASKI Resource Management, SENES Consultants Limited and SRK Consulting limited (ASKI, SENES & SRK) 2012. *Remedial Options Evaluation & Feedback Workshop – Former Eldorado Beaverlodge Properties.* Prepared for Cameco Corporation. July.

Beck, L.S. 1969. *Uranium Deposits of the Athabasca Region*. Saskatchewan Mineral Resources. Report 126. P 59.

Cameco Corporation (Cameco) 2010a. *Conceptual Site Model: Eldorado Beaverlodge Properties. Revision 1.* April.

Cameco Corporation (Cameco) 2010b. *Beaverlodge Project - Screening Level Risk Assessment*. September.

Cameco Corporation (Cameco) 2009. *Ace Creek Characterization Report – Decommissioned Beaverlodge Mine/Mill Site.* December.

Canada North Environmental Services Limited Partnership (CanNorth) 2012. *Beaverlodge Decommissioning – 2011 Aquatic Studies Deep Basin Sediment Sampling.* Prepared for Cameco Corporation. Draft. January.

Canada North Environmental Services Limited Partnership (CanNorth) 2011a. *Beaverlodge 2009 Aquatic Macrophyte Sampling Program.* Prepared for Cameco Corporation. February.

Canada North Environmental Services Limited Partnership (CanNorth) 2011b. *Beaverlodge Decommissioning – Ace Bay 2009 Sediment and Benthic Invertebrate Sampling Program.* Prepared for Cameco Corporation. April.

Canada North Environmental Services Limited Partnership (CanNorth) 2010. *Beaverlodge Decommissioning - Minewater Reservoir Aquatic Investigations.* Prepared for Cameco Corporation. July.

Eldorado Resources Limited 1986. *Decommissioning of the Beaverlodge Mine/Mill Operations and Reclamation of the Site. Vol 6. Departure with Dignity*. October.

Eldorado Resources Limited 1983. *Decommissioning of the Beaverlodge Mine/Mill Operations and Reclamation of the Site. Vol. 5. Plan for the Close-Out of the Beaverlodge Site.* April.

Golder Associates Ltd. (Golder) 2010a. *Results of Field Investigations in the Areas of the Decommissioned Fay-Verna, Hab and Dubyna Mines.* Letter dated October 28, 2010 to Mr. Michael Webster, Cameco Corporation.

Golder Associates (Golder) 2010b. *Results of the Investigation into the Remediation of Flowing Boreholes near the Ace/Fay Shaft and Mill Complex at the Decommissioned Beaverlodge Mine.* Letter dated February 8, 2010 to Mr. Michael Webster, Cameco Corporation.

Hamer, C.E., B.E. Halbert, M. Webster and J. M. Scharer 2012. *Assessment of model adequacy and parameter identifiability for predicting contaminant transport in the Beaverlodge Lake Area, Canada.* Water Pollution XI. Eleventh International Conference on Water Pollution Modelling, Monitoring and Management. Lyndhurst, England. July.

Saskatchewan Ministry of Energy and Resources 2009. *Institutional Control Program: Post Closure Management of Decommissioned Mine/Mill Properties Located on Crown Land in Saskatchewan.*

SENES Consultants Limited (SENES) 2012a. *Beaverlodge Quantitative Site Model.* Prepared for Cameco Corporation. May.

SENES Consultants Limited 2012b. *Risk Evaluation for Uranium City Country Foods Study.* Prepared for Cameco Corporation. Draft. May.

SENES Consultants Limited (SENES) 2009. *Beaverlodge Mine Site Integrated ERA and SOE 1983-2007.* Prepared for Cameco Corporation. January.

SENES Consultants Limited and SRK Consulting Limited (SENES & SRK) 2012. *Costing Study – Potential Remedial Options – Former Beaverlodge Mine.* Prepared for Cameco Corporation. March.

SRK Consulting Limited (SRK) 2011. *Assessment of Stream Flow Diversions-Former Eldorado Beaverlodge Sites.* Report to Cameco Corporation. October.

SRK Consulting limited (SRK) 2010. *Pit Slope Stability Inspection Report – Beaverlodge Project.* Prepared for Cameco Corporation. December.

SRK Consulting limited (SRK) 2010. *Waste Rock Stability Assessments – Former Eldorado Beaverlodge Sites.* Prepared for Cameco Corporation. December.

SRK Consulting Limited (SRK) 2009. *Remedial Options Workshop Report – Former Eldorado Beaverlodge Sites*. Prepared for Cameco Corporation. July.