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Abbreviations

AGRASID	Agricultural Regions of Alberta Soil Inventory Database
$CaCl_2$	calcium chloride
CCE	calcium carbonate equivalent
EC	electrical conductivity
GIS	geographic information system
LAA	local assessment area
LCC	agricultural land capability
LiDAR	Light Detection and Ranging
PDA	project development area
PET	Potential Evapotranspiration
TSS	total suspended solids

9.0 ASSESSMENT OF POTENTIAL EFFECTS ON TERRAIN AND SOILS

The scope of the assessment and existing conditions for terrain and soils are presented in Volume 3A, Section 9.1 and Section 9.2, where the analysis of effects of the Project during construction and dry operations is also presented. Section 9 of this volume assesses the effects of the Project on terrain and soils during flood and post-flood operations. The temporal boundary for the flood and post-flood operations is indefinite, since the Project is a permanent installation. The scope has been influenced by ongoing stakeholder consultation (Alberta Government 2016) and by the terms of reference for the Springbank Off-stream Reservoir Project (ESRD 2015; CEAA 2016).

Flooding would involve addition of new materials to soil and changes in soil drainage conditions while post-flood drawdown has the potential to change terrain stability. The analysis of effects evaluates flood intensities for the 1:10 year, the 1:100 year, and the design floods. These modelled floods differ in the area affected, nature and magnitude of changes that may be introduced to terrain and soils. The three events are analyzed independently without interaction or sequential flooding events.

The scope of assessment for the flood and post-flood phases includes six additional soil parameters not considered in the analysis of effects during construction and dry operations phases.

Additional mitigation, compared to mitigation listed for construction and dry operations phases, are presented. The change in soil parameters is evaluated for its contribution to Agricultural Land Capability class (LCC) change compared to post-construction and dry operations (For description of LCC measurement see Volume 4, Appendix G). Class 1 has no limitation for cereal crops while class 7 is not suitable for such crops. Although the changes to LCC is used as a base to describe soil changes following floods, most of the area of the reservoir would not be used for agriculture once the Project is constructed. The exception is the area north of Springbank Road, which may be used for grazing. As discussed in Section 12 of Volume 3A, following construction, the primary reservoir would be a flood management zone, not accessible to the public and with opportunities for research on flood effects on soils, vegetation and wildlife habitat.

9.1 PROJECT INTERACTIONS WITH TERRAIN AND SOILS

Table 9-1 identifies the Interaction of the Project with terrain and soils. These interactions are discussed in detail in Section 9.2 in the context of effects pathways, standard and project-specific mitigation and residual effects. A justification for no interaction is provided following the table.

Table 9-1 Project-Environment Interactions with Terrain and Soils

Project Components and Physical Activities	Environmental Effect		
	Change to Terrain Stability	Soil Quality	Soil Quantity
Flood Operation			
Reservoir filling	–	-	-
Reservoir draining	✓	✓	✓
Post-flood Operation			
Soil drainage and drying	✓	✓	✓
Reservoir sediment partial cleanup	–	✓	✓
Channel maintenance	–	-	-
Road and bridge maintenance	–	-	-
NOTES: ✓ = Potential interaction – = No interaction			

Reservoir filling during normal flood operation is not expected to interact with terrain stability because flooding would mainly result in the increase of soil pore water pressure on slopes that are relatively flat to gentle and inherently stable. However, on sloping terrain (e.g., channel banks) the increase in soil pore water pressure may be partially offset by an increase in toe support provided by water at the slope base. Channel maintenance and road and bridge maintenance during post-flood operation are not expected to interact with terrain stability or soils because these activities would not occur on or would minimally disturb slopes prone to landslides (e.g., natural channel banks, slopes greater than 20 percent). Reservoir sediment cleanup is expected to be minimal with coarser sized material being removed only where necessary. This is not expected to affect terrain stability.

Reservoir filling during flood operations is also not expected to substantially affect the LCC or quality or quantity of soils because of the very short time frames involved and of the mitigations that would be employed to control soil erosion.

Table 9-2 presents the potential effects, effect pathway and measurable parameters for terrain and soils during flood and post-flood operations.

Table 9-2 Potential Effects, Effects Pathways and Measurable Parameters for Terrain and Soils

Potential Environmental Effect	Effect Pathway	Measurable Parameters and Units of Measurement
Flood Operation		
Change to terrain stability	High soil pore water pressures resulting from reservoir draining of saturated soils, soil drainage and drying, and reservoir sediment partial cleanup can destabilize channel banks within the reservoir. Below the low-level outlet, reservoir draining would increase stream flow both in magnitude and duration above baseline conditions and would destabilize channel banks and river escarpments.	Terrain stability class ratings
Post-flood Operation Phase		
Change in soil quality and quantity	Flooding and post-flooding activities caused by the project alter soil chemical, physical, and drainage properties that can change agricultural land capability. Capability changes result from erosion, deposition, changes to soil moisture content, and salinization. Change to soil aeration, organic matter content, texture, mineralogy and related soil nutrient cycling processes also influence capability. Dust mobilization and deposition could affect the agricultural land capability of receiving soils. Soil depth change due to sediment deposition can alter land capability.	• agricultural land capability, using the Land Suitability Ratings System for Agricultural Crops (Agronomic Interpretations Working Group 1995), with a key focus on soil parameters: • soil drainage regime • soil anoxia • soil erosion due to surface water (Wall et al. 2002) • deposition effects on soil physical properties • deposition effects on soil chemical properties • addition of soil through deposition of new material (depth) • salinization • wind erosion risk (Coote and Pettapiece 1989)

9.2 ASSESSMENT OF RESIDUAL ENVIRONMENTAL EFFECTS ON TERRAIN AND SOILS

9.2.1 Analytical Assessment Techniques

9.2.1.1 Terrain

Project effects, after the application of mitigation measure, on terrain stability during reservoir draining operation in the local assessment area (LAA) is assessed by means of terrain stability class ratings (BCMOF and BCMOE 1999). The qualitative terrain stability class rating is based on field data and professional judgement and considers the baseline surficial material physical properties, slope steepness, soil drainage and existing geomorphological processes.

9.2.1.2 Soils

Project effects on soils are evaluated in terms of LCC (Agronomic Interpretations Working Group 1995) and wind erosion risk change (Coote and Pettapiece 1989), the latter after the application of mitigation. Agriculture land capability is chosen to represent soil quality and quantity because the soils in this region have moderate potential based on regional capability assessments for agriculture (Alberta Soil Information Centre 2003) and loss of agricultural capability was identified as an important concern by stakeholders. LCC is measured differently than in the post-construction and dry operations phase, where it included climate, topography and soil profile factors. For flood- and post-flood phases, LCC is based only on soil profile factors because topography and climate factors are not affected by flooding. Wind erosion risk by the method of Coote and Pettapiece (1989) is suitable for the region because local wind patterns may interact with the Project to affect soil quality in the LAA.

The analysis first quantifies the degree of change in the parameter, followed by evaluating the effect of that parameter on agricultural land capability or wind erosion risk. Changes in wind erosion risk are evaluated for potential changes in soil quality.

9.2.2 Change to Terrain Stability

Reservoir draining operations of the Project have the potential to affect terrain stability through rapid drawdown and shift in stream flow regime.

9.2.2.1 Project Pathway

Reservoir draining has the potential to affect terrain stability along channel banks within the reservoir. Rapid reservoir draining can subject a slope to a high soil pore water pressure gradient (increased shear stress) and cause potential instability (Terzaghi 1943). There is a direct relationship between pore water pressure and soil drainage; therefore, the project pathways described in the section 9.2.3 are similarly applicable to terrain stability.

During release of reservoir water, the low-level outlet channel would be subject to a major shift in stream flow regime which could destabilize stream banks (see Hydrology section). Current bankfull discharge in the outlet channel is approximately 1.0 m^3/s, as estimated from monitoring data (Stantec 2016). The currently planned maximum discharge rate for the low-level outlet for the design flood is 27 m^3/s over a 43-day draining period.

9.2.2.2 Mitigation

Key mitigation to reduce the effect of soil pore water pressure change within the reservoir during reservoir draining include:

- drawdown of stored flood waters will be conducted in a controlled manner to avoid soil erosion and to maintain slope stability.

Standard post-flood mitigation to be employed to lessen the extent of residual effects on terrain stability due to a substantive shift in the stream flow regime within the low-level outlet channel include:

- slope stability inspection and monitoring will be conducted on the structures to detect and repair any sloughs or failures.
- repair and re-armour as required the channel banks to stabilize slopes where flood diversion flows have caused erosion.
- seed and revegetate the channel banks with native seed or erosion control mix to improve bank stability where flood diversion flow has caused erosion of the vegetation.

9.2.2.3 Project Residual Effects

The predicted residual effects on slopes after recommended post-flood mitigation would be a temporary imbalance in soil pore water pressure within the reservoir. This could result in minor, localized bank slumping immediately following reservoir draining and before the dissipation of pore water pressure.

The predicted residual effects on the low-level outlet channel after recommended post-flood mitigation would be a shift in stream flow regime resulting in a change in channel planform (change in terrain polygons) and an increase in local bank instability (the likelihood of landslide initiation of some banks mapped as low to moderate would increase). Based on the hydrological regime modelling for the floods (Section 6). The order of magnitude increase in the stream flow regime for the 1:100 year and design floods would result in a predicted adverse residual effect on terrain stability along the low-level outlet channel.

9.2.3 Change in Soil Quality and Quantity

9.2.3.1 Project Pathways

The flooding, draining and post-flood conditions of the primary reservoir basin can affect LCC through changes to the soil drainage regime, soil nutrient properties (soil anoxia), physical and chemical properties, soil depth, soil salinity, water erosion and wind erosion risk. These pathways are summarized below. More detail can be found in the soil technical data report in Volume 4, Appendix G Attachment 9A.

Soil Drainage Regime

Soils would become saturated during flood events. The combination of fine textures, low permeability, high water tables, and a variable and uncertain atmospheric moisture deficit would interact to keep soil moisture at high levels for a period (Shook and Pomeroy 2011). Changes to the soil drainage regime would have immediate effects on soil quality and change the LCC. Other effects from soil saturation include reduced trafficability on the reservoir surface.

Soils would be submerged over intervals ranging from 5 days for the 1:10 year flood to more than 67 days for the design flood events, sufficient time to saturate the unsaturated zone of the soil profile and parent material.

Soil Anoxia (Change in Soil Nutrient Properties)

Submergence and saturation would lead to soil anoxia in all soils subject to flooding. Related effects include increased solubility of anions such as phosphorus, reduction of manganese and iron, denitrification, and conversion of organic carbon to methane (Brady and Weil 2010; Bohn et al. 1985). While nutrient properties are not directly included in LCC ratings, they are critical to ecological function of these soils as well as interactions with aquatic systems. Given that these processes are most active in topsoil horizons, they potentially could affect LCC by loss of organic carbon. However, because of the relatively short period of potential anoxia, soil oxygen levels in topsoil horizons would be maintained in the aerobic range soon after reservoir drainage, typically within one or two months of reservoir drainage. Soil anoxia is not discussed further.

Physical Properties of Soils (Change in LCC)

Flooding would introduce new sediment to the soils in the off-stream reservoir. Sediment may affect physical properties of the soil, including texture and related water holding capacity. Sediment is expected to be dominantly in the sand size class, in contrast to the existing particle size dominated by silt and clay. These changes to soil texture and water holding capacity may result in LCC change. Sediment depths greater than 0.2 m are expected to trigger changes to LCC. Maximum depth of sediment predicted for the design flood exceeds 3 m.

Chemical Properties of Soils (Change in LCC)

The sediment is expected to be primarily calcium-carbonate in mineralogy because it is derived from the limestone rich beds of the Rocky Mountains. The primary effect of calcite on soil is through its effect on soil pH. For that reason, all sediment is considered as calcite, as a conservative (overestimate of effect) assumption.

Soil Depth (Change in LCC)

Sediment added to the soil surface has the potential to affect the quantity of soil and related LCC ratings.

Soils Salinity (Change in LCC)

The Project would elevate water tables beneath flooded areas, which in turn may change the vertical distribution of soil salinity in the vadose zone, with implications for LCC. Soils are currently non-saline and non-sodic, although there is evidence that imperfectly drained soils have higher salinity than soils of other drainage regimes.

Water Erosion (Change in LCC)

Both reservoir filling and reservoir drainage are expected to contribute to water erosion, especially of topsoil horizons. Water traveling along the diversion channel and entering the reservoir may retain sufficient energy to erode topsoil. Water erosion may favor the colloidal fraction (clay-organic associations), over larger particle size classes, leading to a depletion of organic carbon and clay. Turbulence in the water column is expected to maintain suspended silt and clay in the water column; therefore, these fractions may be lost. Loss of topsoil would affect ratings for LCC (see Section 6 for discussion of flood dynamics and sediment removal and deposition).

Wind Erosion Risk (Change in LCC)

Changes in wind erosion risk during post-flood phases has the potential to interact with other soil receptors. Wind erosion may transport sediment with higher CCE and contribute to pH change in receiving soils. Wind erosion risk in the LAA may change after sediment deposition above baseline soil profiles. A sediment depth of 3 cm or greater is expected to trigger a change in wind erosion risk if texture of sediment differs from baseline topsoil texture.

9.2.3.2 Mitigation

Physical Properties of Soils and Soil Depth (Change in LCC)

Most sediment deposition thicknesses would be less than 0.5 m but there would be some areas with 1.0 m to 3.0 m thickness and a few isolated areas with up over 4 m thickness (see Section 6). This sediment is not expected to be removed.

Chemical Properties of Soils (Change in LCC)

There is no planned mitigation of higher calcium carbonate content in soil and higher pH. Time periods are likely too short to allow any measurable removal of free carbonates through leaching. Therefore, pH can be expected to remain constant for the time periods considered. This would not be critical to plant community function because many prairie upland and wetland plant communities would not be limited by this pH range.

Soils Salinity (Change in LCC)

There is no planned mitigation for changes in the distribution of soil soluble salts following flooding episodes. The area would not be used for agricultural purposes.

Water Erosion (Change in LCC)

The following mitigation measures would be implemented:

- Infrastructure, such as the diversion channel, will contain additional elements that are designed to slow flow velocity and turbulence. The design of the diversion channel outfall into the off-stream reservoir includes energy dissipation blocks to control flows and reduce erosion. The low-level outlet outfall that returns flood waters back into the Elbow River will have erosion protection and energy dissipation blocks.
- Rip rap will be installed along some edges of the diversion channel side slopes in critical areas such as outside curves, and on the water face of the off-stream Storage Dam.,
- Riprap will be installed where the diversion channel enters the reservoir, to reduce flow velocity and limit soil erosion.

- In areas of the reservoir where sediment deposition may make surfaces susceptible to wind erosion, application of a tackifier may be used to mitigate soil erosion.
- Agronomic or native seed species may be included with the tackifier to provide longer-term stability to the soils.

Wind Erosion Risk (Change in LCC)

In areas of the reservoir where sediment deposition may make surfaces susceptible to wind erosion, tackifier will be considered to mitigate the effects. Agronomic or native seed species may be included with the tackifier to provide longer-term stability to the soils. A tackifier could be applied to the surface regardless of trafficability issues. A tackifier will reduce the wind erosion risk to negligible (Appendix G, Attachment 9A).

9.2.3.3 Project Residual Effects on Soil Quality and Quantity (Change in LCC)

Soil Drainage (Change in LCC)

The time needed to restore soil-water content to an equilibrium value is estimated through a water balance calculation. Rate of change in soil moisture content is determined from potential evapotranspiration rates (loss) applied to a soil profile that starts at maximum water content (saturated) and ends when a target water content (background moisture content) is reached. The quantity of water in the soil is estimated from hydraulic properties (porosity, field capacity, depth to water table). The soil dewatering limit is equated to the mid-point moisture content for a typical prairie soil. The methods for determining soil moisture contents is presented in Volume 4, Appendix G, Attachment 9A.

Table 9-3 shows the time required, in years (one year = one growing season), to achieve soil moisture reductions to the background moisture content.

Table 9-3 Dewatering Rates of Soil Units after Reservoir Drainage

Soil Units	Profile Depth (m)[a]	Time to Background Moisture Content[b] To Profile Depth (years)
DVG1[c] Dunvargan	2.5	0.79
DVFS1 and FSH1[c] Dunvargan and Fish Creek	2.0	0.54
DVFS2 and FSH2[c] Dunvargan, Fish Creek and other Fish Creek phases	1.75	0.48
POT1[c] Pothole Creek	1.0	0.34
POT2[c] Pothole Creek and other Fish Creek phases	1.25	0.41
POT6[c] Pothole Creek and other Fish Creek phases	1.5	0.49

Table 9-3 Dewatering Rates of Soil Units after Reservoir Drainage

Soil Units	Profile Depth (m)[a]	Time to Background Moisture Content[b] To Profile Depth (years)
POT7[c,d] Pothole Creek, Regosols and Gleysols	1.0	0.34
MSTB1[fd]Mesa Butte and Twin Bridges	1.0	0.40
SRC1[d] Sarcee	1.50	0.51
SRC4[d] Sarcee and other Sarcee phases	1.50	0.49
TBR1, TBSR1, TBR2[d] Twin Bridges, Twin Bridges & Sarcee, Twin Bridges and other Twin Bridges phases	1.50	0.73
TBR4[d] Twin Bridges and other Twin Bridges phases	1.50	0.68
TBRgr1, TBRgr2[d] Twin Bridges gravelly and other Twin Bridges gravelly phases	1.50	0.51
ZGC1[d] Miscellaneous coarse textured Gleysolic	1.50	0.67
ZREC Miscellaneous reclaimed land	2.00	0.45
ZREC2A Miscellaneous reclaimed land, well drained, fine textured	2.00	0.45
ZREC2B Miscellaneous reclaimed land, imperfectly drained, fine textured	1.25	0.32
ZREC2C Miscellaneous reclaimed land, poorly drained, fine textured	1.00	0.28
ZREC3A Miscellaneous reclaimed land, well drained, fine over coarse textured	2.00	0.97
ZREC3B Miscellaneous reclaimed land, imperfectly drained, fine over coarse textured	1.25	0.58
ZREC3C Miscellaneous reclaimed land, poorly drained, fine over coarse textured	1.00	0.45
DEP1 to 5[e] Recent flood deposits	N/A	N/A

NOTES:

[a] Profile depths vary among units to account for differences in background water table depths. Profile depth is the depth from the surface to the saturated zone.

[b] Assumes average precipitation for the year. Measured in units of years, with years understood to mean growing seasons. One growing season is the length of the year when mean air temperature is greater than 0 and plants are transpiring. Rate of drawdown calculated as the ratio of water content of soil (mm) and annual atmospheric moisture deficit (potential evapotranspiration – precipitation) (mm). Potential evapotranspiration estimated at Calgary International Airport was 966 mm (Alberta Government 2013) while precipitation measured at Springbank Airport was 470 mm (Environment Canada and Climate Change 2016). Unsaturated drainage assumed to be negligible due to extremely slow rate of decline in regional water table depth. See Attachment 9A for estimates of dewatering rates when lake evaporation rates are used instead of potential evapotranspiration.

[c] fine textured soil unit

[d] medium to coarse textured soil unit

[e] dewatering rates in flood deposits expected to be controlled by free drainage, not evapotranspiration because of the very coarse textures of flood deposits

Moderately well to well drained soils would shift towards poor drainage regimes for the first year following a flood event and then rebound to an equilibrium wetness that would be similar to pre-flood wetness, at least for the areas affected by 1:100 year and design floods. For the 1:10 year flood, drainage is likely to remain imperfectly drained, and events of similar magnitude would tend to establish a new range of drainage in this area of the reservoir. Soils that are poorly drained currently (Gleysolic) are less affected by the increasing wetness imposed on the landscape. They return to baseline conditions moisture content somewhat faster than the upland Chernozemic. Likewise, moisture regime change is less in Gleysolic soils than in the Chernozemic group, where a change of three drainage classes occurs.

Water Erosion (Change in LCC)

There may be sufficient time between flood events that soils would naturally ameliorate effects of erosion on loss of topsoil mass or quality (organic matter content). This is especially true for the areas affected by the design flood, where several decades of vegetation productivity may restore organic carbon levels in soil (Landi et al. 2003). Losses of soil organic carbon due to flooding are unlikely to be substantive, and likely much less than would happen if these grasslands were converted to cereal agriculture (Martel and Paul 1974). During the inter-flood periods, soil organic carbon levels are likely to rise in newly-deposited sediment through plant-soil interactions. Because of mitigation measures, soil erosion rates from water flow are not expected to affect LCC ratings.

Physical Properties of Soils and Soil Depth (Change in LCC)

Sediment would be added to the soil surface for a flood event but not deposited evenly in the reservoir. The sedimentation modelling provided by Hydrology (See Section 6) was used to evaluate the effect of this deposition on soil properties through integration with LCC estimates.

The LCC ratings for flood deposits greater than 0.2 m in thickness have been evaluated. Sediment depths that range from 0.2 to 0.7 m in thickness have a substantial effect on agricultural land capability, especially because the very coarse texture compared to fine textured soils present at baseline. Sediments greater in thickness than 1 m have the largest effect on LCC change as compared to other sediment thickness depths. Effects were included in those presented in Table 9-10.

Chemical Properties of Soils (Change in LCC)

Flooding is expected to increase soil pH permanently to a value controlled by the solubility of calcium carbonate. At sediment depths expected for the 1:100 year and the design floods, soil pH is expected to reach values of 8.2 (in-water pH measure), which contributes to a decline in LCC.

Soils Salinity (Change in LCC)

Samples of groundwater obtained through monitoring of the uppermost sampled surficial layers show elevated EC and higher concentrations of sodium and sulfate anions (see Section 5) than were observed in soil samples collected from the soil profile (see Volume 4, Appendix G, Terrain and Soils Technical Data Report). Upward flow gradients were also observed, suggesting that groundwater discharge conditions are present (see Section 5). Such hydrogeologic settings have potential for salinization (Henry et al. 1985).

The reservoir has soils of very low salinity and no concerns with shallow bedrock (see Volume 4, Appendix G, Terrain and Soils Technical Data Report). An upward shift of the water table could lead to an areal expansion of soils affected by upward movement of sodium or other soluble salts. In turn, this could lead to increased sodicity and salinity in flooded soils.

Wind Erosion Risk (Change in LCC)

Sediment is expected to be coarser textured than pre-flood soil and, therefore, of higher erosion potential. Sediment depths of 3 cm or greater would result in changes of wind erosion risk to existing pre-flood soil conditions. Potential loss of vegetation that may accompany flooding and deposition also raises wind erosion risk. Furthermore, the chinook winds common to the area mean that wind erosion concern extends through the winter months (Larney et al. 1995). Sediment is also expected to have high calcium carbonate content and, therefore, if transported to adjacent areas, it may affect soil capability through pH change.

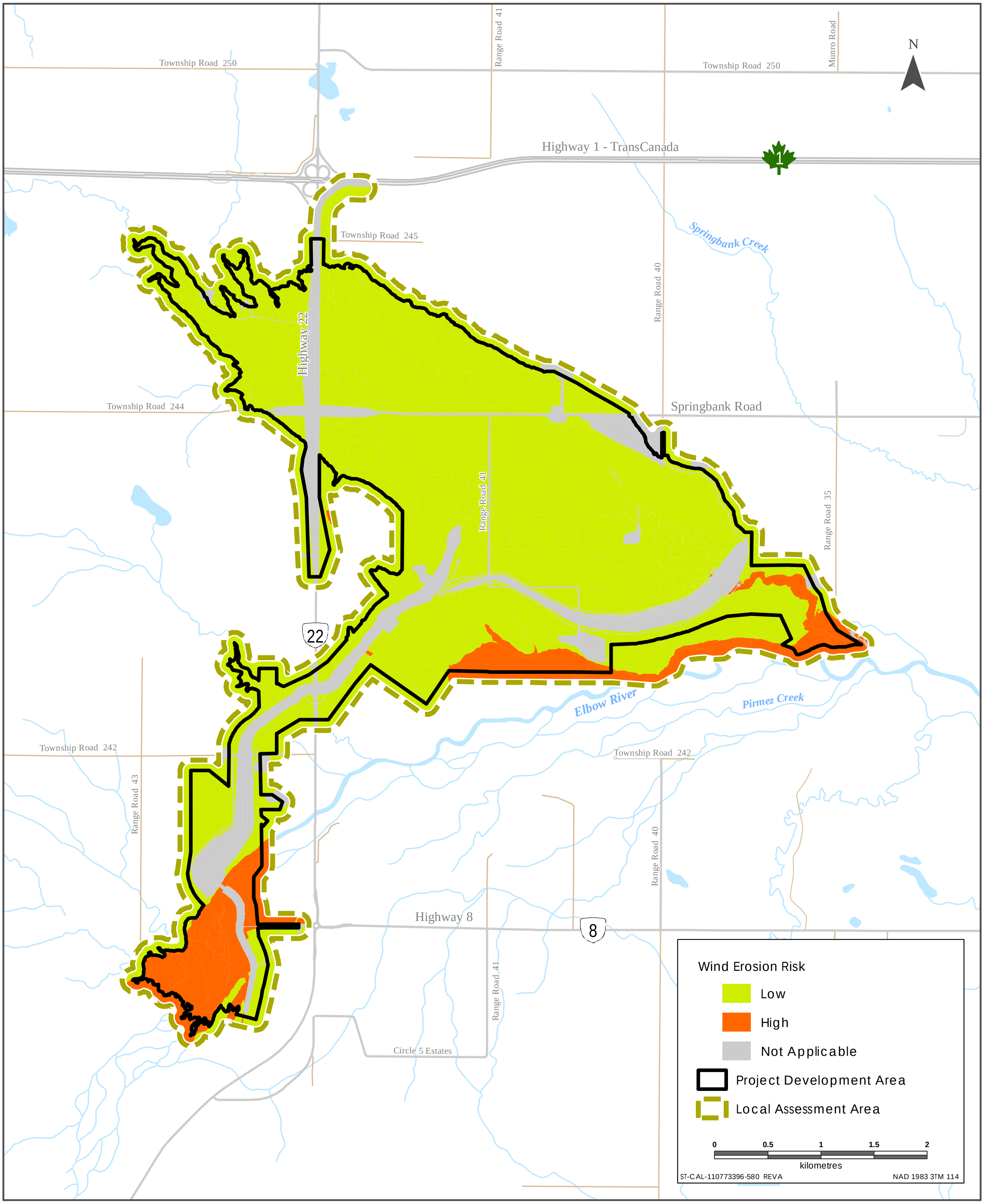
Dust from the area of sedimentation, if mobilized by wind erosion, may be deposited on soils elsewhere in or beyond the LAA. At sufficiently high deposition rates or long periods of deposition, receiving soil pH and related LCC may be affected through the same mechanisms as in the reservoir itself.

Effects of sediment addition on wind erosion risk for the LAA following a design flood are presented in Table 9-4 and Figures 9-1 and 9-2. The risks assume that tackifiers and revegetation are required and are in place for mitigation. The reductions in wind erosion risk following mitigation are such that most newly deposited sediment can be held in place against loss to wind erosion. Effect of wind erosion loss on adjacent soils is therefore considered negligible, as is the effect on LCC both in the LAA and outside. The reason for a decrease in area of extent of low and high erosion risk after the flood is that mitigations (tackifier) are applied only to areas of design flood deposition. Areas beyond the flood deposition retain their pre-flood wind erosion risk.

Table 9-4 Areal Extent of Wind Erosion Risk (ha) after mitigation following the Design Flood

Risk Class	Pre-Flood[1]	Design Flood[2,3]
Negligible	0.0	176.0
Low	1419.3	1257.5
Moderate	0.0	0.0
High	224.3	210.1
Severe	0.0	0.0
Not Applicable	242.9	242.9

NOTES:
[1] pre-flood occurs post-construction but not yet affected by flood deposition
[2] assumes that texture of deposited material is loamy sand
[3] assumes tackifier used in areas affected by flood deposition



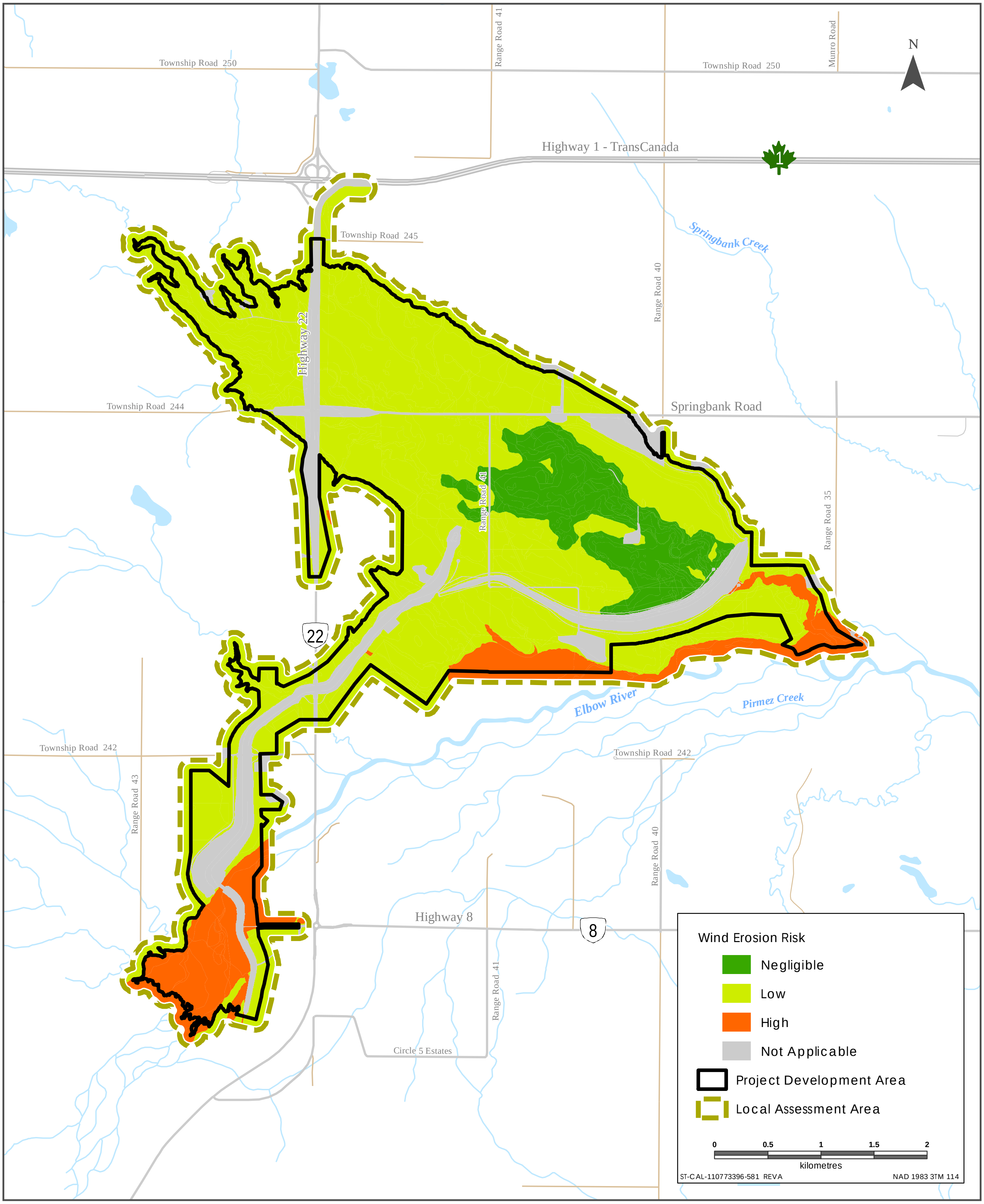
Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.

Distribution of Wind Erosion Risk Class for the Terrain and Soils Project Development Area and Local Assessment Area at Pre-Flood

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 9-1



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.

Distribution of Wind Erosion Risk Class for the Terrain and Soils Project Development Area and Local Assessment Area after the Design Flood Event, Full Mitigation

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 9-2

Summary of Change in LCC

LCC for soil units for pre-flood and each modelled flood is presented in Table 9-5. Project effects on dynamic properties that affect LCC effects are measured twice: early in the post flood period to assess maximum effect on soil capability and a second time when dynamic soil properties have reached equilibrium. While the period of maximum effect may be as short as one year following a flood event, uncertainties in soil dewatering rates suggest that this period is uncertain. Other more permanent effects, i.e., pH, are considered to reach equilibrium immediately, even though actual changes would occur more slowly.

Table 9-5 LCC as a Function of Flood, by Soil Unit

Soil Unit	LCC for pre-Flood Conditions	1:10 Year Flood		1:100 Year Flood		Design Flood	
		Maximum Effect[1]	Equilibrium[2]	Maximum Effect[1]	Equilibrium[2]	Maximum Effect[1]	Equilibrium[2]
DVFS1	2	4	3	5	2	5	2
DVFS2	2	4	4	5	2	5	3
DVG1	2	4	3	5	2	5	2
FSH1	2	5	3	5	2	5	2
FSH2	2	5	4	5	2	5	2
MSTB1	2	3	3	3	3	3	3
POT1	6	7	7	7	6	7	6
POT2	5	7	7	7	5	7	5
POT6	4	6	6	6	4	6	4
POT7	5	6	6	6	5	6	5
SRC1	1	2	1	2	2	2	2
SRC4	2	2	2	2	2	2	2
TBR1	2	2	2	2	2	2	2
TBR2	2	2	2	2	2	2	2
TBR4	2	2	2	2	2	2	2
TBR6	2	2	2	2	2	2	2
TBRgr1	4	4	4	4	4	4	4
TBRgr2	4	4	4	5	5	5	5
TBSR1	2	2	2	2	2	2	2
ZDL	N/R	N/R	N/R	N/R	N/R	N/R	N/R
ZGC1	5	5	5	5	5	5	5
ZREC	3	6	4	6	3	6	3

Table 9-5 LCC as a Function of Flood, by Soil Unit

Soil Unit	LCC for pre-Flood Conditions	1:10 Year Flood		1:100 Year Flood		Design Flood	
		Maximum Effect[1]	Equilibrium[2]	Maximum Effect[1]	Equilibrium[2]	Maximum Effect[1]	Equilibrium[2]
ZREC2A	2	5	4	5	2	5	3
ZREC2B	4	5	4	5	4	5	4
ZREC2C	6	7	6	7	6	7	6
ZREC3A	2	4	2	4	2	4	2
ZREC3B	2	4	3	4	2	4	2
ZREC3C	5	7	5	7	5	7	5
DEP1[3]	N/A	N/A	N/A	nd[4]	nd	6	5
DEP2	N/A	N/A	N/A	nd	nd	6	6
DEP3	N/A	N/A	N/A	nd	nd	6	6
DEP4	N/A	N/A	N/A	nd	nd	6	7
DEP5	N/A	N/A	N/A	nd	nd	6	7

NOTES:

[1] duration of maximum effect predicted to extend for at least one year, assuming natural drainage, the ability of plants to maximize evapotranspiration, and the occurrence of average precipitation rates over the interval

[2] equilibrium moisture content established after soil water introduced by flooding has been removed from the soil profile and water tables have declined. These changes occur through a combination of evapotranspiration to the atmosphere and percolation to deeper groundwater or surface water e.g., the Elbow River.

[3] DEP consists of flood deposits equal to or thicker than 0.2 m overlying existing soil profiles, with various drainage regimes. See notes to Table 9-3. N/A = not applicable; the modelling of the 1:10 year flood did not predict sediment thickness. The results of the design flood are presented as the worst-case scenario.

[4] nd not determined

Table 9-6 provides a summary of changes in land capability that can be expected for the design flood, relative to pre-flood conditions. Ratings for the post-construction (pre-flood) condition based on soil profile only, are presented in Figure 9-3. Ratings for the post-design flood are presented in Figures 9-4 and 9-5. The figure that shows the maximum effect is intended to integrate the dynamic changes introduced for soil drainage due to flooding, while equilibrium effects reflect drier soil moisture that accompanies natural dewatering. Both maximum and equilibrium snapshots account for the contribution of sedimentation on LCC.

Area of LCC 1 remains nearly constant from pre-flood, through the period of maximum effect and later equilibrium. Area of LCC 2 (mode of the distribution) declines dramatically during the immediate post-flood period, but increases again once equilibrium is achieved. LCC 2 remains the mode at equilibrium. Area of LCC 5 increases by more than a factor of 4 between pre-flood and the maximum effect, but decreases to an extent similar to its pre-flood value. The changes to the remaining LCC classes follow a similar pattern, although extents of class 6 and 7 are much higher at equilibrium than at pre-flood. These latter areas are associated with the areas of thicker flood deposition.

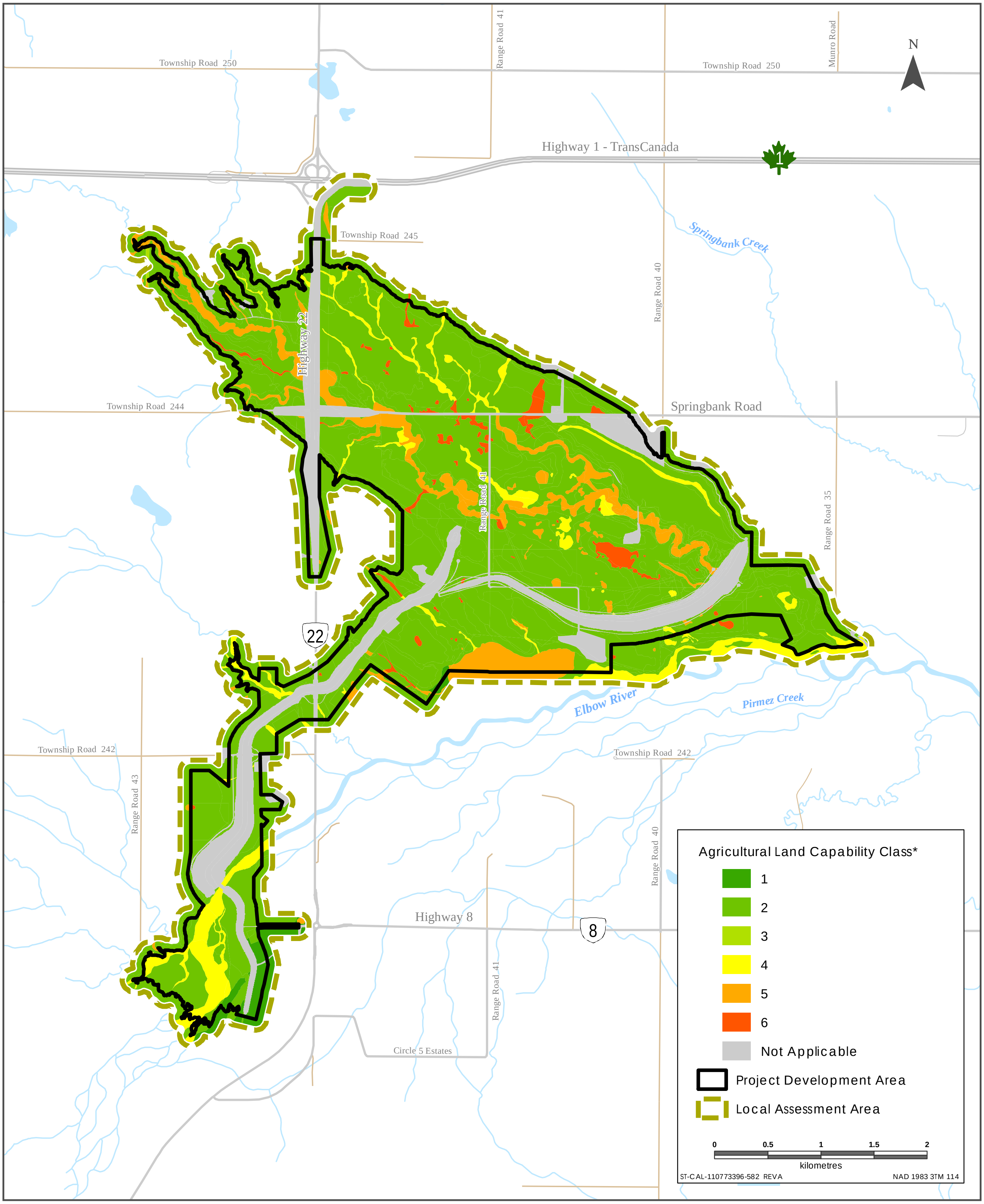
Table 9-6 Summary of LCC Extent at Post-Construction and for Design Flood

Areal Distribution of Agricultural Land Capability (Soil Profile) in the LAA (maximum effect, equilibrium) for pre-flood and for the Design Flood, (ha)			
		Design Flood	
LCC	Pre-Flood (ha)	Maximum Effect[1] (ha)	Equilibrium[2] (ha)
1	32.0	31.9	31.9
2	1338.0	768.5	1096.7
3	1.1	1.1	165.4
4	117.2	85.1	111.0
5	129.1	546.9	150.1
6	26.3	189.6	48.3
7	0.0	20.5	40.3
N/A	242.9	242.9	242.9
Total	1886.5	1886.5	1886.5

NOTES:

[1] duration of maximum effect predicted to extend for at least one year, assuming natural drainage, the ability of plants to maximize evapotranspiration, and the occurrence of average precipitation rates over the interval

[2] equilibrium moisture content established after soil water introduced by flooding has been removed from the soil profile and water tables have declined. These changes occur through a combination of evapotranspiration to the atmosphere and percolation to deeper groundwater or surface water e.g., the Elbow River.



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.
**Refer to Tables D7-15 and D7-16 for Agricultural Land Capability Class descriptions.*

Agricultural Land Capability (Soil Profile) for the Terrain and Soils Project Development Area and Local Assessment Area at Pre-Flood

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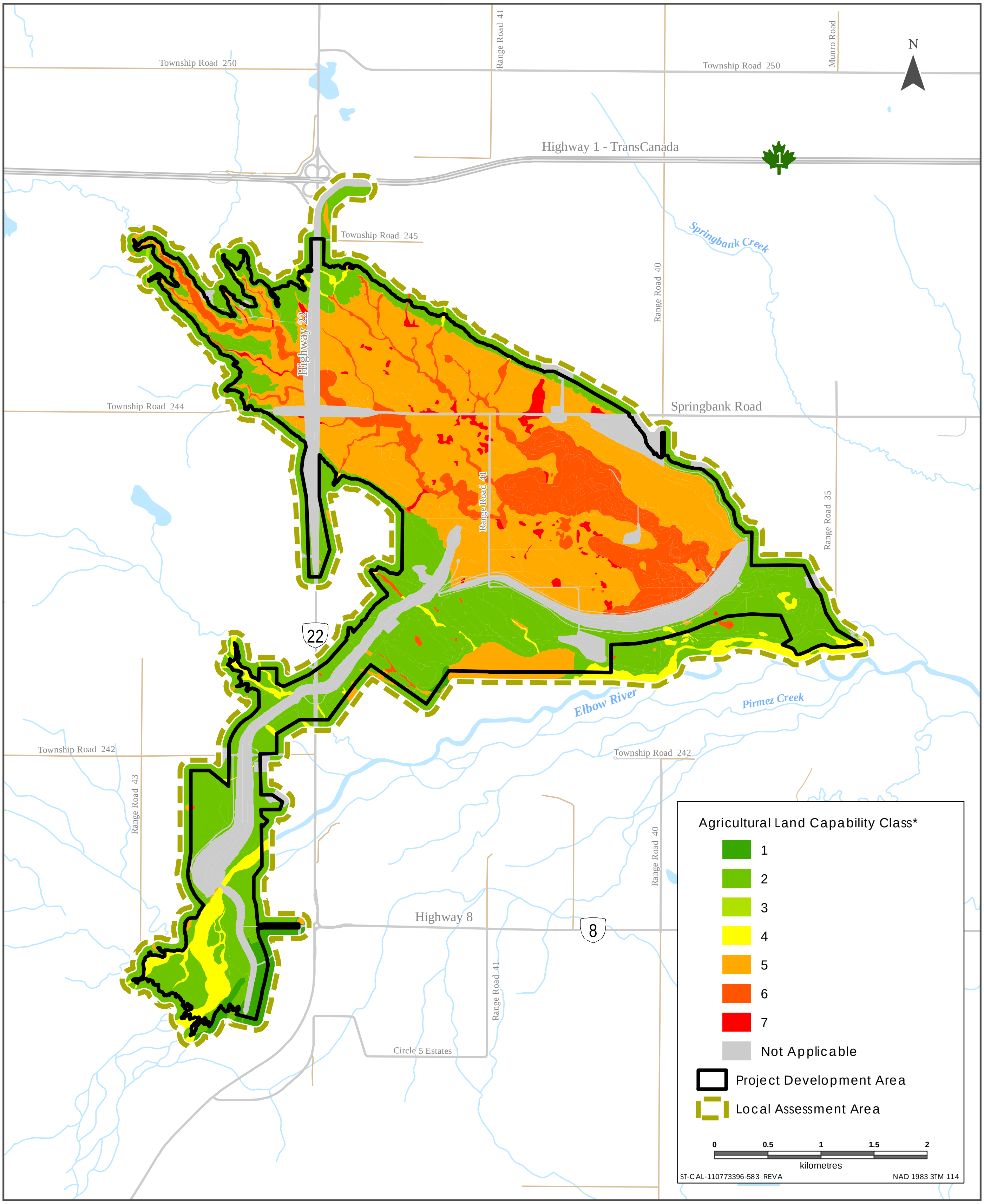
Figure 9-3



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.
**Refer to Tables D7-15 and D7-16 for Agricultural Land Capability Class descriptions.*

Agricultural Land Capability (Soil Profile) for the Terrain and Soils Project Development Area and Local Assessment Area after the Design Flood Event, Maximum Effect

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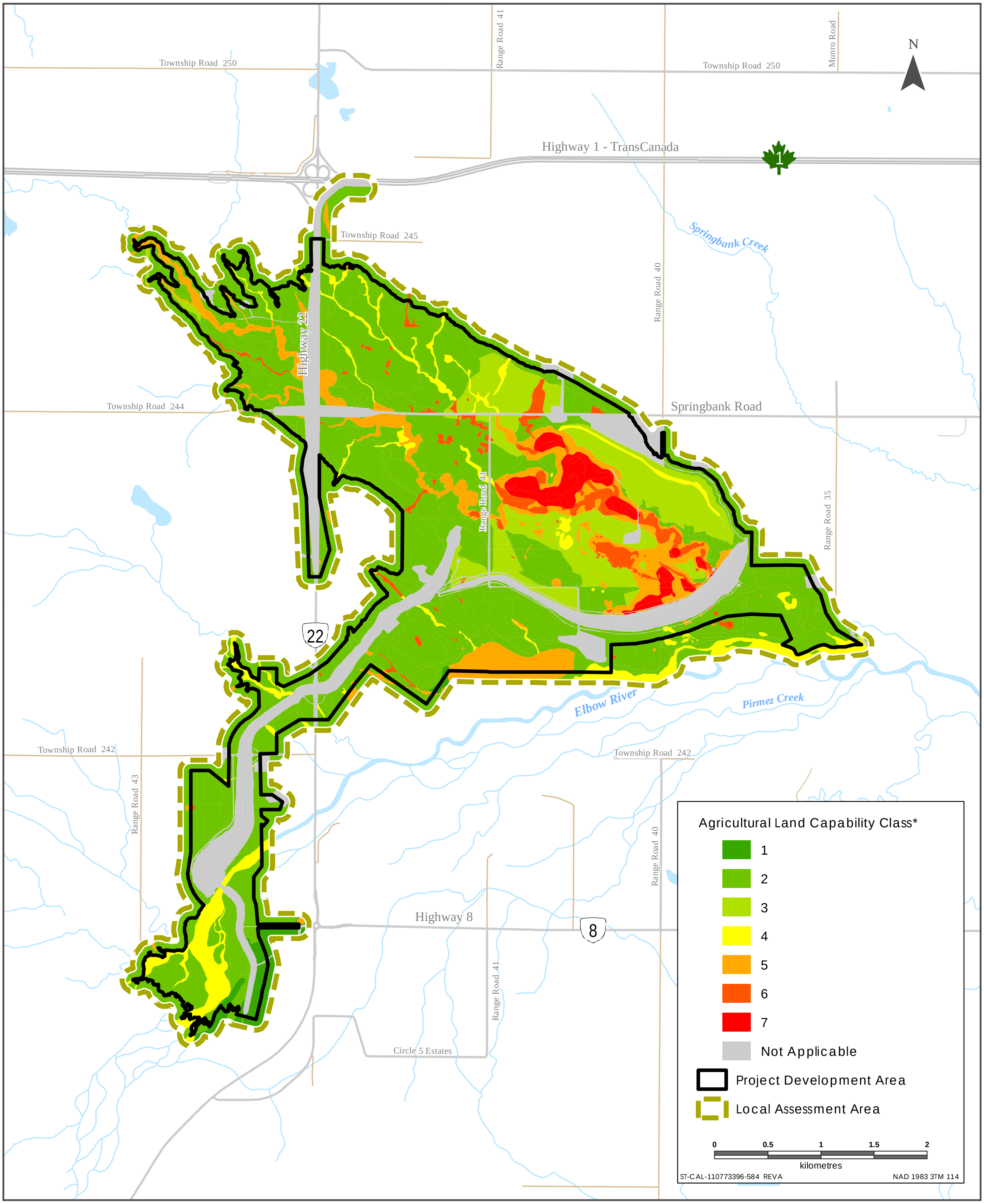
Figure 9-4



Sources: Base Data - Government of Alberta, Government of Canada, Thematic Data - Stantec Ltd.
**Refer to Tables D7-15 and D7-16 for Agricultural Land Capability Class descriptions.*

Agricultural Land Capability (Soil Profile) for the Terrain and Soils Project Development Area and Local Assessment Area after the Design Flood Event, Equilibrium Effect

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Figure 9-5

9.2.4 Summary of Project Residual Effects

Table 9-7 summarizes the residual environmental effects on terrain and soils during flood and post-flood operations.

Table 9-7 Project Residual Effects on Terrain and Soils

Flood	Residual Effects Characterization								
	Project Phase	Timing	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Ecological and Socio-economic Context
Terrain Stability									
1:10 Year	PF	N/A	A	L	PDA	ST	IR	R	U
1:100 Year	PF	N/A	A	M	LAA	LT	IR	I	U
Design	PF	N/A	A	M	LAA	LT	IR	I	U
Change in Soil Quality and Quantity (change in LCC)									
1:10 Year	PF	N/A	A	L	LAA	MT	S	I	U
1:100 Year	PF	N/A	A	H	LAA	LT	S	I	U
Design	PF	N/A	A	H	LAA	LT	S	I	U

KEY

See Table 9-2 in Volume 3A for detailed definitions.

Project Phase
F: Flood Operation
PF: Post-flood Operation

Timing Consideration
S: Seasonality
T: Time of day
R: Regulatory

Direction:
P: Positive
A: Adverse
N: Neutral

Magnitude:
N: Negligible
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Duration:
ST: Short-term;
MT: Medium-term
LT: Long-term

N/A: Not applicable

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

Ecological/Socio-Economic Context:
D: Disturbed
U: Undisturbed

Overall, the predicted results on terrain stability are low magnitude change (minor bank slumping) for the 1:10 year flood and moderate magnitude for the 1:100 year and design floods, typically immediately after post-flood operations. Timing is not applicable because effects from Project activities would be similar regardless of season or other timing characteristics.

The predicted results on soil quality and quantity (LCC) are adverse, of high magnitude and irreversible effect with a long-term duration. Flooding effects to quality and quantity of soil are adverse in consequences for LCC. Magnitude is high because the change in area of the mode exceeds 10% in area of the LCC mode at existing conditions. The area of LCC mode (class 2) declines from 1338.0 ha to 1096.7, a change of -241.3 ha (-18%). Duration is long because soil effects are expected to exceed 25 years. Timing is not applicable because effects from Project activities would be similar regardless of season or other timing characteristics.

9.3 DETERMINATION OF SIGNIFICANCE

As defined in Section 9.1.6 of Volume 3A, a significant environmental effect on terrain and soils is one that results in:

- A change in terrain stability resulting in an increase in areas with a moderate to high likelihood of landslide initiation as compared to baseline conditions that cannot be offset through mitigation, or
- A change in soil quality or quantity resulting in a reduction in soil capability, which cannot be offset through mitigation or compensation measures,

The effect of the Project on terrain stability during flood and post-flood operations and offset through mitigation is anticipated to be adverse. Rapid reservoir draining would lead to a short-term, high soil pore water pressure gradient that can cause localized bank instability. For all three floods, the soil pore water pressure imbalance is of relatively short duration and potential instability is predicted to be small and localized to the flooded channel banks, therefore, the adverse residual effect within the reservoir is considered not significant.

However, downstream of the low-level outlet, the planned maximum discharge rates for the 1:100 year and design floods are an order of magnitude greater than the existing condition at bankfull discharge. In these floods, locally significant channel changes are anticipated; however, subsequent floods may be mitigated (e.g., slope stability monitoring and slope stabilization) such that the long-term adverse residual effects may become less with an extent that is confined to the local area of assessment (LAA).

The predicted effects on soil quality and quantity are adverse, of high magnitude and irreversible effect with a long-term duration. Flooding would saturate the soils within the reservoir, leading to chemical change that in some cases is not reversible. Flooding would also bury baseline soil profiles beneath coarse textured sediment resulting in a loss of agricultural capability and an increase in wind erosion risk unless fully mitigated. Despite these changes to soil quality and quantity the change in land use away from agricultural means that these changes are not significant.

9.4 PREDICTION CONFIDENCE

Specific predictions of terrain instability should be considered approximations. Nevertheless, project residual effects on terrain stability are predictable with high confidence; supported by high level assessment of erosion potential under various release rates (Stantec 2016).

Guidelines of terrain survey intensity level were followed to identify terrain attributes in the LAA (BCMOF and BCMOE 1999). Existing terrain data are detailed and based on 66 inspection sites and are integrated with previous surficial materials mapping by Moran (1986) and soils mapping by MacMillan (1987). In addition, soils information from 360 inspection points and borehole data from more than 100 geotechnical investigations were also cross-referenced. Slope steepness and characterization of topography was based on LiDAR data with one-meter and fifteen-meter accuracy. The combination of office and field data and professional judgement was used to inform the terrain stability mapping. No slope stability modelling was completed.

The confidence in these predictions on soil quality and quantity is:

- Moderate degree of confidence in soil drainage rates and related LCC effects
- Moderate degree of confidence in effectiveness of mitigations for preventing water erosion of soils due to water during flood and post-flood
- Moderate degree of confidence in chemical effects on soil
- High degree of confidence in effectiveness of wind erosion mitigations on preventing effects to receiving soils
- Moderate degree of confidence in predictions of changes in potential for salinization.

9.5 CONCLUSIONS

9.5.1 Change in Terrain Stability

Within the reservoir, the change in terrain stability following flood and post-flood operations for all modelled floods is predicted to be an adverse effect of low magnitude, not significant and with an extent that is confined to the PDA. For the low-level outlet channel, the change in terrain stability following flood and post-flood operations for the 1:100 year and design floods is predicted to be an adverse effect of moderate magnitude, significant and with an extent that is not confined to the PDA.

9.5.2 Change in Soil Quality and Quantity (LCC)

Within the reservoir, the change in LCC is predicted to be a long term, adverse and irreversible effect of high magnitude. However, since land use would change from agricultural if the project is approved, the effects on soil are not considered significant.

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