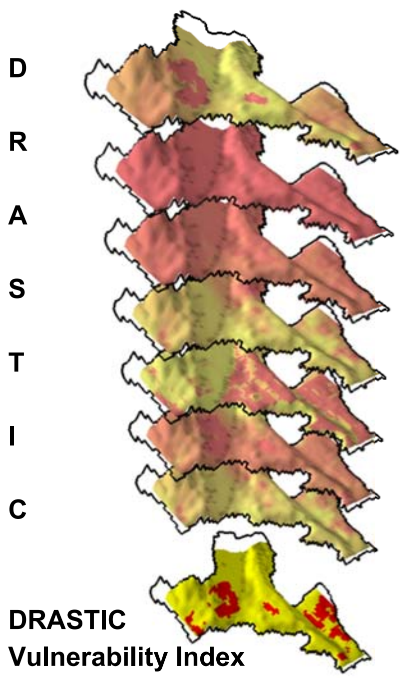
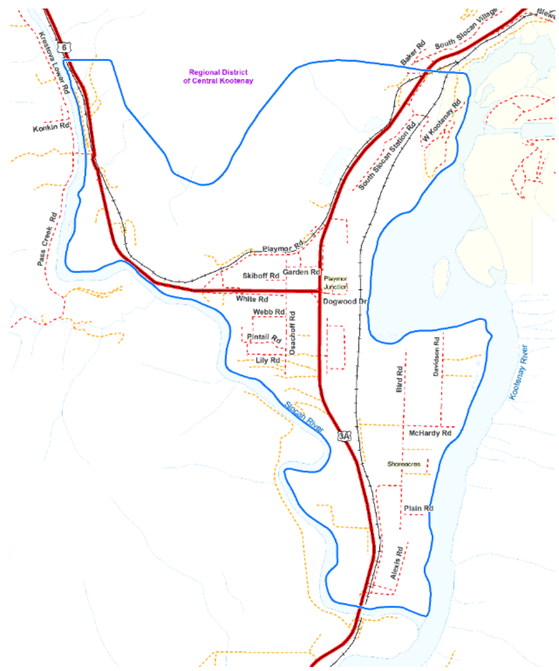
REGIONAL DISTRICT OF CENTRAL KOOTENAY

DRASTIC-BASED VULNERABILITY STUDY

SHOREACRES AQUIFER

MAY 2019 (REVISION1 JUNE 2019)





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1 INTRODUCTION

Regional District of Central Kootenay (RDCK) retained WSP Canada Inc. (WSP) to conduct a Vulnerability Study based on the DRASTIC methodology for parts of the sand and gravel aquifer located between Nelson and Castlegar, centered on Playmor Junction in British Columbia (BC). The aquifer is referred to herein as the Shoreacres Aquifer, and the BC aquifer reference number is #0514.

The RDCK manages community planning and development of the rural areas within the regional district. Within Electoral Areas I and H, the communities of Shoreacres, Playmor Junction, Crescent Valley, and the Voykin subdivision are supplied with domestic groundwater from aquifer #0514. Per the 2016 Electoral Area I Comprehensive Land Use Bylaw, "*Wastewater disposal is a concern in several communities, such as Shoreacres where the groundwater aquifer is high and vulnerable to contamination, and in areas where lot sizes may be too small to adequately replace older waste water disposal systems when they fail."* There is concern that residential development has reached or exceeded capacity and that there is vulnerability to local water supply from septic tanks effluent or other surface contaminants finding its way into existing wells.

The objective of this study is to develop aquifer vulnerability mapping to assist with land management and land use practices in an area of known groundwater quality issues that is under development pressure.

1.1 SCOPE OF WORK

The DRASTIC method is an overlay and index method developed by the United States Environmental Protection Agency (US EPA) (US Environmental Protection Agency, 1985); this method has been widely used in other areas of British Columbia. The name DRASTIC represents each of the seven input parameters used in the GIS-based mapping process.

In applying the DRASTIC method to the subject area, WSP has:

1. Reviewed available background information including the aquifer classification work sheet, surficial geology and soils mapping, and water well logs;
2. Reviewed well logs and published maps as a means of 3D modelling areas with differing vulnerability within the study area;
3. Developed a means of ranking the relative vulnerability of areas identified in the previous task. This may include, but is not limited to, information such as soil types, presence or absence of fine-grained layers, depth to groundwater, surface water drainages, and current land uses;
4. Identified potential recharge areas, discharge areas and areas with known, or potential, groundwater quality issues; and
5. Used GIS mapping to present the vulnerablity ranking of the study area using a 50 by 50 m grid.

The outputs of the DRASTIC method is a series of maps, representing each letter of the model and the final vulnerability ranking for the Shoreacres Aquifer. The methods employed and work completed have been outlined in this report.

2 BACKGROUND

2.1 STUDY AREA

The Shoreacres Aquifer is located along the eastern shore of the Slocan River, until it confluences with the Kootenay River in the area of Playmor Junction, as shown on Figure 1.

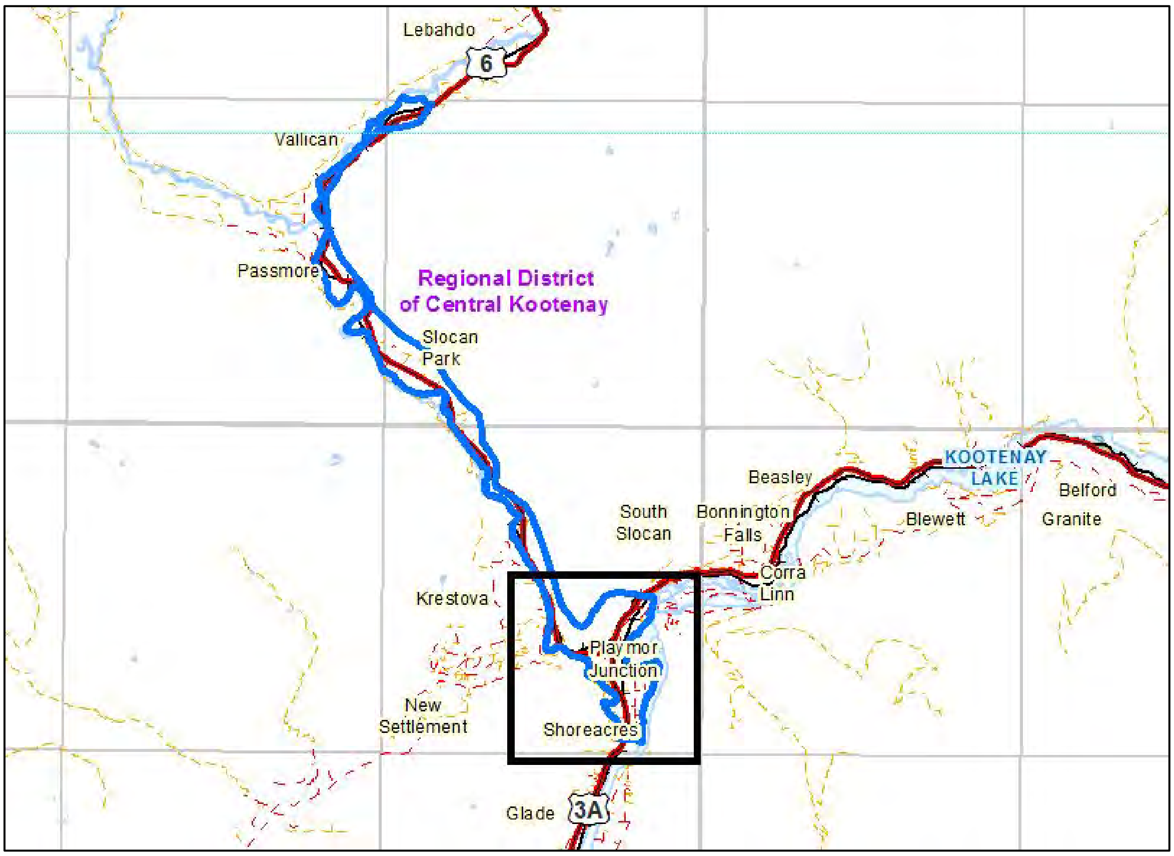

Figure 1. Regional Map. Aquifer #0514 is shown by the blue line and the study area lies within the black square.

The western boundary of the aquifer follows the Slocan river. The eastern boundary is defined by quaternary deposits mapping, and the southeastern boundary is the Kootenay River.

The study area includes the southern portion of the aquifer highlighted by the black outline in Figure 1 (Government BC, 2019). Figure 2 shows a more detailed map of the study area.

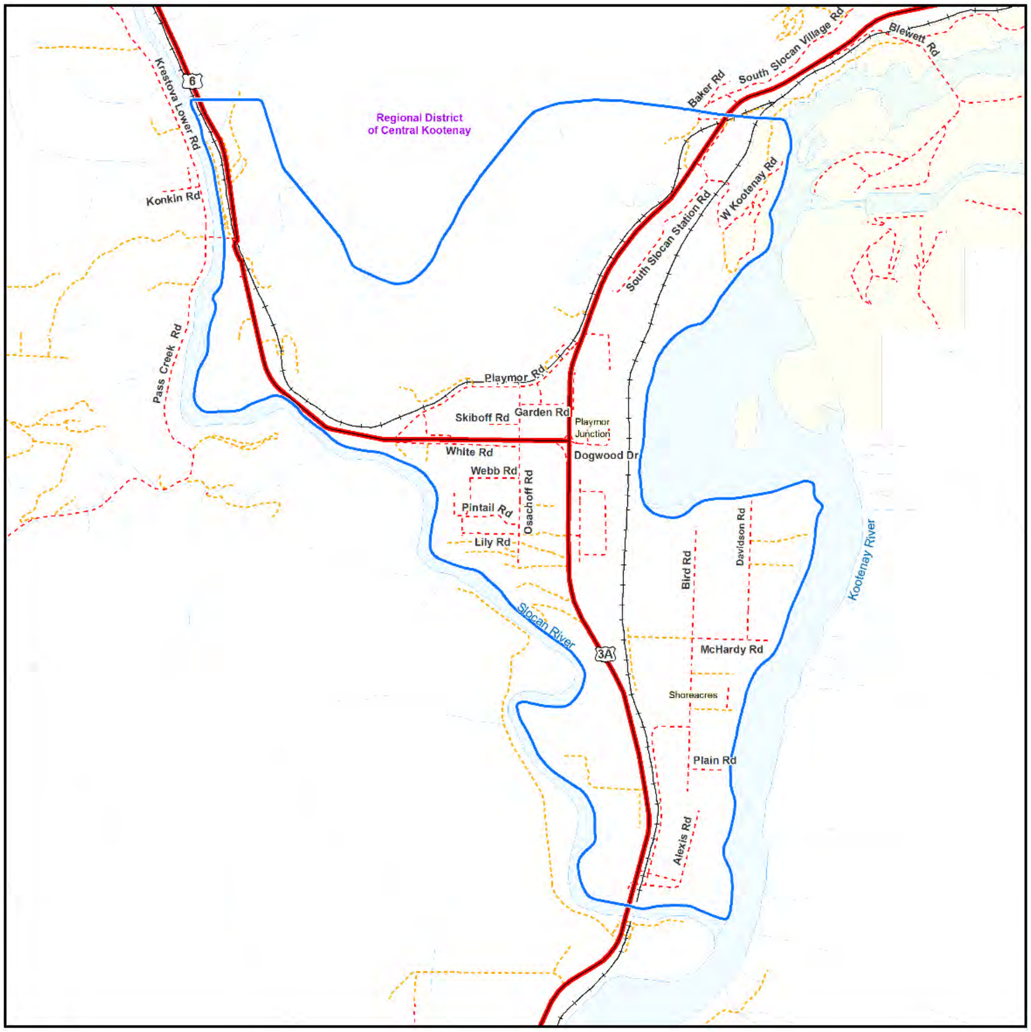

Figure 2. The study area is defined by the blue line, which is the southern portion of Shoreacres Aquifer #0514.

2.2 GEOLOGY AND HYDROGEOLOGY

This section provides a summary of the published aquifer classification worksheet for Aquifer #0514 (Lowen Hydrogeology Consulting Ltd., 2016).

The Shoreacres Aquifer is split into a *Type* and *Subtype*; the type is listed as, “a glaciofluvial sand and gravel aquifer at surface, as well as sand and gravel aquifers identified occurring underneath till or glaciolacustrine deposits.” The subtype is listed as, “confined sand and gravel aquifers underneath till, in between till layers, or underlaying glaciofluvial deposits.”

The aquifer materials are overlain by a mixture of clay, silt, sand, and gravel. Surficial soil consists of three separate soil types: Kinert, Gillis, and Glenlilly. These soils are derived from glaciofluvial and glaciofluvial ice contact processes. The aquifer formation itself is comprised of glaciofluvial sand, gravel, or sand and gravel.

The aquifer is classified as a partially confined aquifer with the confining layers containing many windows of permeable materials. The vulnerability for the entire aquifer is classified as *Moderate*. The productivity is moderate, with yields ranging from 0.13-6.62 L/s.

Groundwater flow direction is controlled by the uplands along the eastern boundary of the aquifer, and by the Slocan and Kootenay rivers on the western and southern boundaries. Groundwater flow is expected to be from the uplands towards the rivers. The aquifer zone near the Slocan River is expected to be hydraulically connected, with a regional flow direction towards the south. Recharge of the aquifer is generally from precipitation and snow melt in the upslope areas, with runoff water percolating through the unconsolidated layers to replenish the aquifer.

Most of the water wells drilled into the aquifer are used for domestic purposes. The quality is typically reported as 'good' with wells producing fresh water. High levels of iron are noted in some of the wells. Well depths range from 1.8 - 163.4 m with a median of 35.1 m and an average depth of 39.6 m.

3 METHODOLOGY

This Vulnerability Study was based on The DRASTIC methodology proposed by the US EPA (Aller. L., 1987). The model is based on the following seven parameters: Depth to water (D), Net Recharge (R), Aquifer Media (A), Soil Media (S), Topography(T), Impact of Vadoze Zone (I), and Hydraulic Conductivity (C).

The model was build in three steps:

1. Each of the seven letters (DRASTIC) is evaluated based on the geology, hydrogeology, or the potential of pollution to the aquifer.
2. The outcome of the first step is either a material classification (such as sand or gravel) or a number (for example depth to water table in meters). The material or the number is then classified using pre-established DRASTIC model values that vary between 1-10.
3. Combining the seven different ratings with different weight indexes provides the Drastic Vulnerability Index (DVI). The formula that is used to get the final vulnerability index is:

$$DVI = 5D+4R+3A+2S+1T+5I+3C$$

Ratings established using physical data are marked in black and the model weight is marked in red.

An overview of the input parameters, ranges, ratings, and relative weighting factors is presented in Table 1 for the DRASTIC model (Arzu Firat Ersoy., 2013).

Table 1. DRASTIC Ranges and Ratings (Provides an overview of the different input parameters, ranges, ratings, and relative weighting)

Parameter	Range	Rating	Description	Relative weighting
Depth to water (D) (feet)	0-5 5-15 15-30 30-50 50-75 75-100 >100	10 9 7 5 3 2 1	Refers to the depth to the water surface in an unconfined aquifer. Deeper water table levels imply lesser chance for contamination to occur. Depth to water is used to delineate the depth to the top of a confined aquifer.	5
Net recharge (R) (in)	0-2 2-4 4-7 7-10 >10	1 3 6 8 9	Indicates the amount of water per unit area of land which penetrates the ground surface and reaches the water table. Recharge water is available to transport a contaminant vertically to the water table, horizontal with in an aquifer.	4
Aquifer media (A)	Massive shale Metamorphic/igneous Weathered met./igneous Bedded sandstone, Limestone, Shale sequences Massive sandstone Massive limestone Sand and gravel Basalt Karst limestone	2 3 4 6 6 6 8 9 10	Refers to the consolidated or unconsolidated medium which serves as an aquifer. The larger the grain size and more fractures or openings with in an aquifer, leads to higher permeability and lower attenuation capacity, hence greater the pollution potential.	3
Soil media (S)	Soil thin or absent Gravel Sand Peat Shrinking and/or aggregated clay Sandy loam LoamSilty loam Clay loam Muck Non-shrinking and non-aggregated clay	10 10 9 8 7 4 5 4 3 2 1	Refers to the uppermost weathered portion of the vadose zone characterised by significant biological activity. Soil has a significant impact on the amount of recharge which can infiltrate into the ground.	2
Topography (T) (slope%)	0-2 2-6 6-12 12-18 >18	10 9 5 3 1	Refers to the slope of the land surface. It helps a pollutant to runoff or remain on the surface in an area long enough to infiltrate it.	1
Impact of vadose zone (I)	Silt/clay Shale Limestone Sandstone Bedded limestone, Sandstone, shale Sand and gravel with significant silt and clay Metamorphic/igneous sand and gravel Basalt Karst limestone	1 3 6 6 6 6 4 8 9 10	Is defined as unsaturated zone material. The significantly restrictive zone above an aquifer forming the confining layers is used in a confined aquifer, as the type of media having the most significant impact.	5
Hydraulic conductivity (C) (GPD/ft2)	1-100 100-300 300-700 700-1,000 1000-2,000 >2,000	1 2 4 6 8 10	Refers to the ability of an aquifer to transmit water, controlling the rate at which groundwater will flow under a given hydraulic gradient. material within the groundwater system	3

To be able to use the DRASTIC methodology for the study area, some of the ranges and ratings have been modified so that they fit with the conditions for the study area. The relative weighting has not been adjusted.

For some of the letters (R, S, T), data is available for every single point throughout the whole study area. But for the other letters (D, A, I, C), data is available only where well logs are available. In the second case, the information for each letter is based on information from water well logs. Figure 3 shows the locations of the water wells, as available from iMapBC (Government BC, 2019), in the study area. In total there were 92 well logs available in the study area.

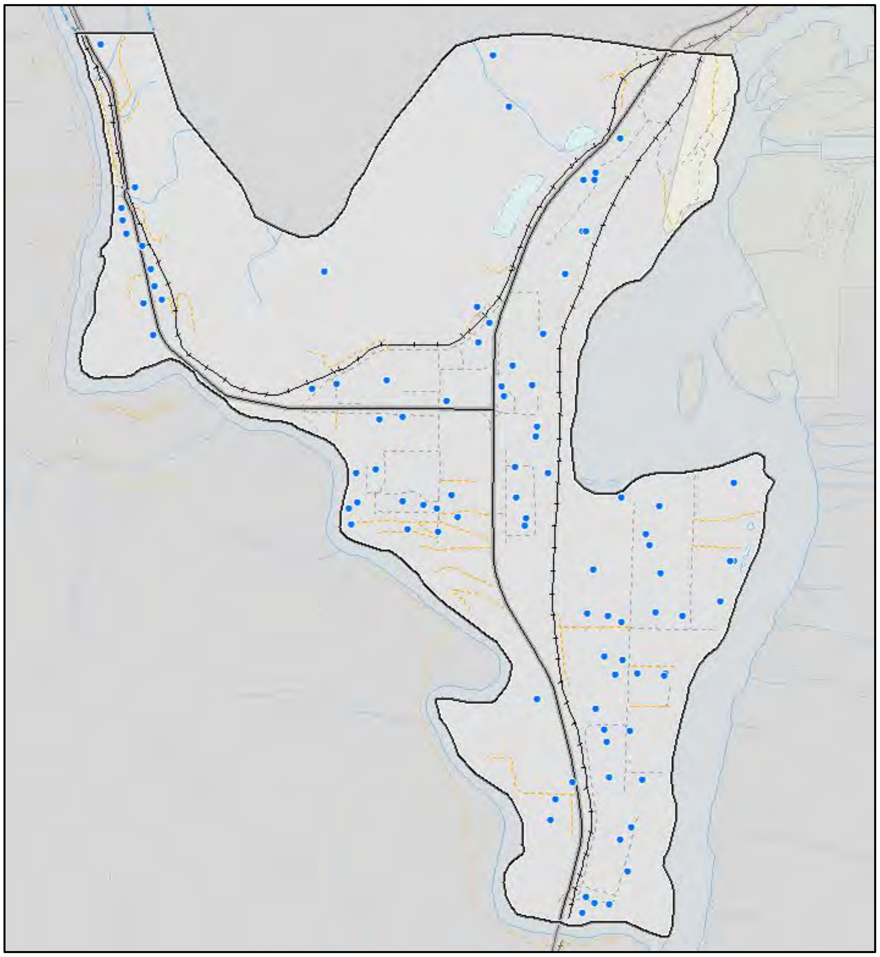

Figure 3. Water well locations as marked with a blue dot.

To represent the data, the study area was gridded into squares of 50 m x 50 m. Letter ratings for the model and the final DVI were calculated for every grid space; the grid is shown on Figure 4. For letters (D, A, I, C) where evaluation data was available only at water well points, data were interpolated using the ArcGIS inverse distance method to establish ratings for the grid spaces between the well points. Due to limited data along the edges of the study area, the inverse distance method was not able to interpolate right up to the edge of the study area boundary.

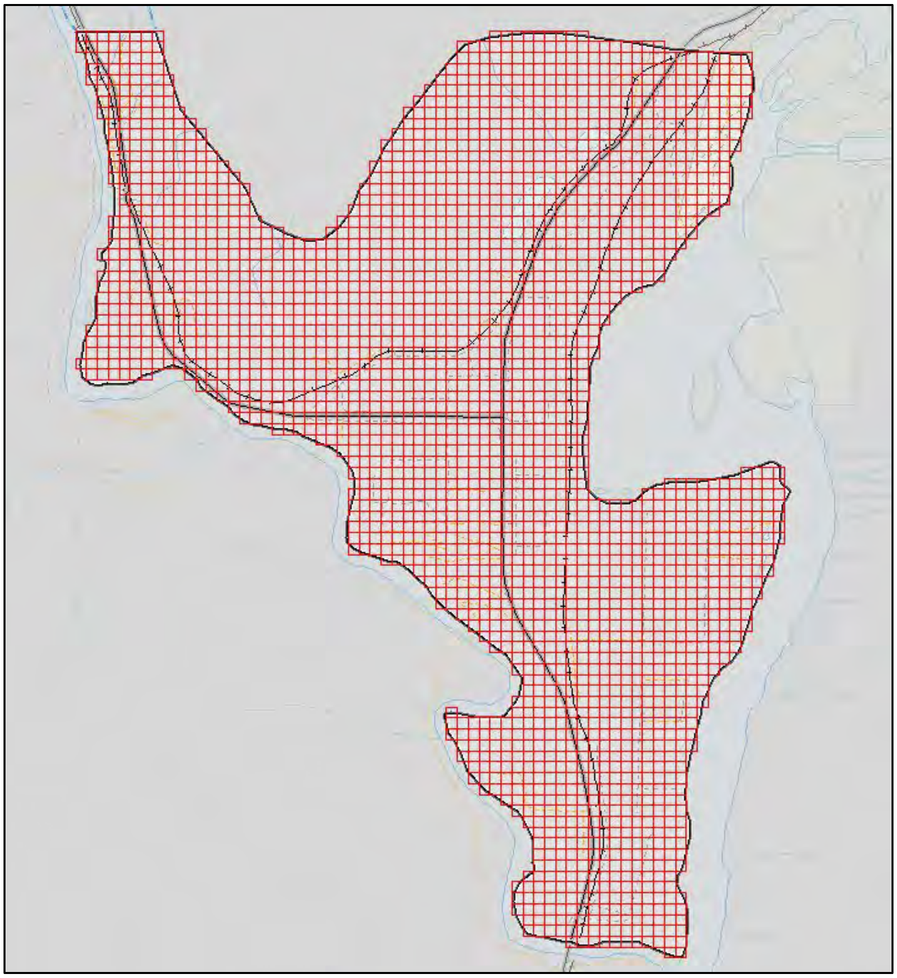

Figure 4. The study area gridded into squares 50 x 50 m. The DRASTIC rating is evaluated for each square.

The evaluation of the individual DRASTIC letters and how ratings were adjusted is presented separately for each letter in sections 4.1-4.7.

Presenting the DRASTIC ratings for each separate letter and calculating the final DVI gives a single index for each square within the study area, and this data can be presented in map format. Table 2 provides an overview of the vulnerability categories.

Table 2. Vulnerability Categories

VULNERABILITY	DRASTIC INDEX	COLOUR ON MAP
Low	0-100	Green
Moderate	100-160	Yellow
High	161+	Red

4 RESULTS

All input data for the DRASTIC model is attached in Appendix A. Large format maps for each of the DRASTIC inputs and the final DRASTIC ratings (DVI) are provided in Appendix B.

4.1 AIR PHOTO REVIEW

A review of local aerial photographs was undertaken to assess if any areas of potential risk to groundwater quality could be identified. Areas of note are presented on Figure 5.

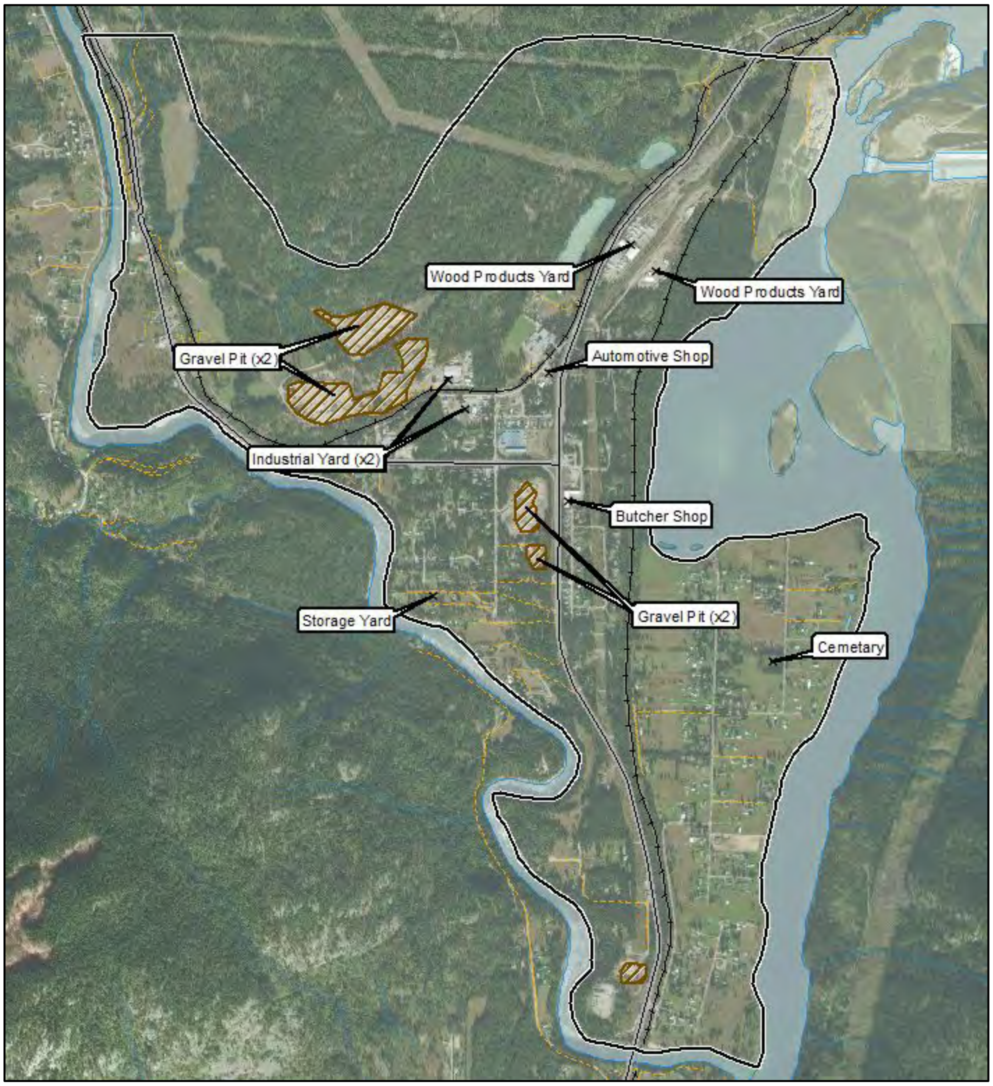

Figure 5. Areas of potential concern.

All of the businesses and activities identified during the air photo review could present a risk to local aquifers in different ways. Some of the identified activities, such as aggregate extraction, effect the vulnerability index as they remove layers of fine-grained materials that protect the vadose zone and shallow groundwater.

The inventory of potential risk areas that could affect the Vulnerability Index were added to the DRASTIC model; in particular, areas of aggregate extraction were flagged and assigned values for the relevant DRASTIC letters.

4.2 INDIVIDUAL DRASTIC LETTERS

4.2.1 D – DEPTH TO WATER TABLE

As depth to groundwater (distance between ground surface and static water level) decreases, vulnerability increases, as contamination has the potential to reach the aquifer quicker and there is less potential for natural attenuation.

The Shoreacres Aquifer is classified as a partially confined aquifer, which includes areas that are unconfined and some areas, if they are large enough, that can be classified as confined. The definition used in this study for a confined well was the definition described by the Ministry of Environment and Climate Change Strategy (Environmental Managment Act, 2017). Water wells were classified as confined if a confining layer of a minimum thickness of 5 m was present. Possible confined areas were established by reviewing the classification of each well and, if a group of more than 6 well logs was present showing confined conditions, the area was flagged as confined.

The first step was to evaluate if there were any areas in the study area that were able to be classified as confined. Evaluation of the lithology from 81 of the available water well logs determined the status of confined/unconfined conditions as shown on Figure 6.

To determine the value of D – depth to water table, the following was completed: For unconfined groundwater conditions, depth to the static water table is used, and for confined conditions, depth to the top aquifer is used.

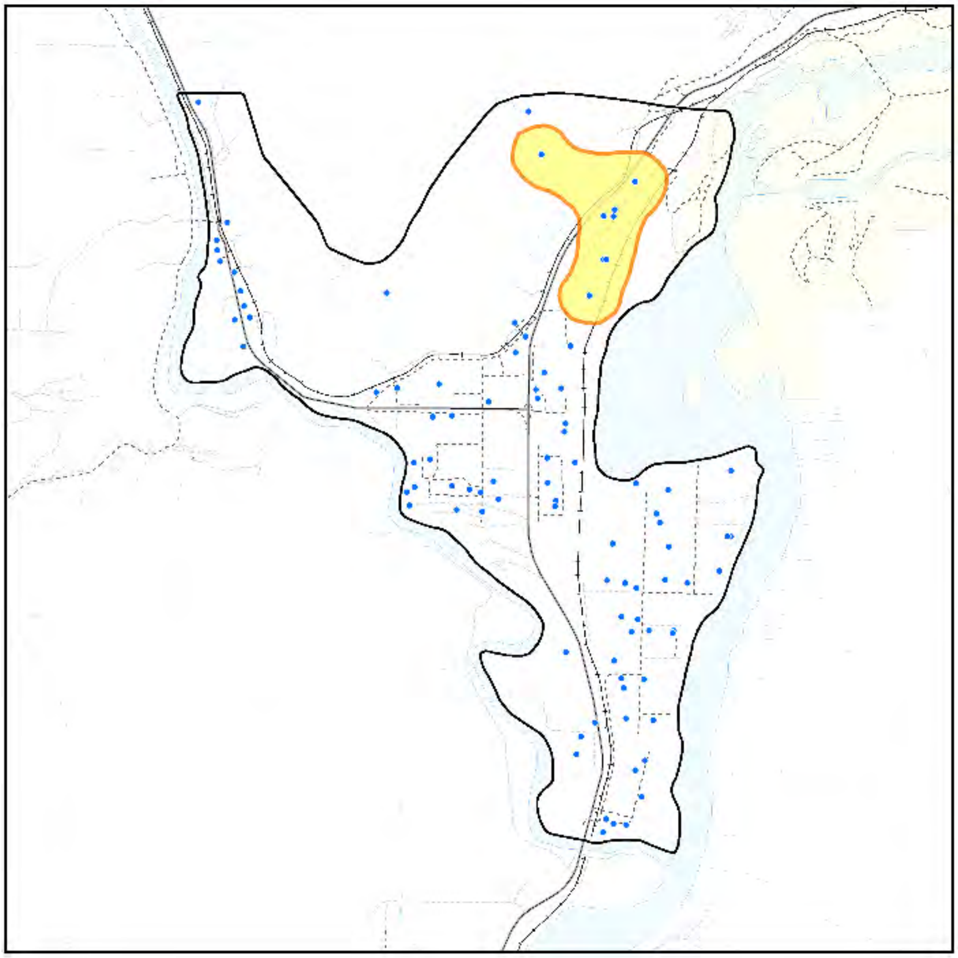

Figure 6. Yellow area is classified as a confined part of the aquifer.

Inside the interpreted confined area of the aquifer, the DRASTIC rating is set to 1. For the rest of the area, where unconfined or partially confined conditions exist, the range in depth to the static water level provides the DRASTIC rating. As the depth information is only available at the water well locations, the depth to water was interpolated for the entire study area using the inverse distance method in ArcGIS.

No modifications to the range and rating system was needed for this layer. Borehole data including static water level and lithology were downloaded from iMapBC (Government BC, 2019). The ArcGIS layer for D is presented on Figure 7.

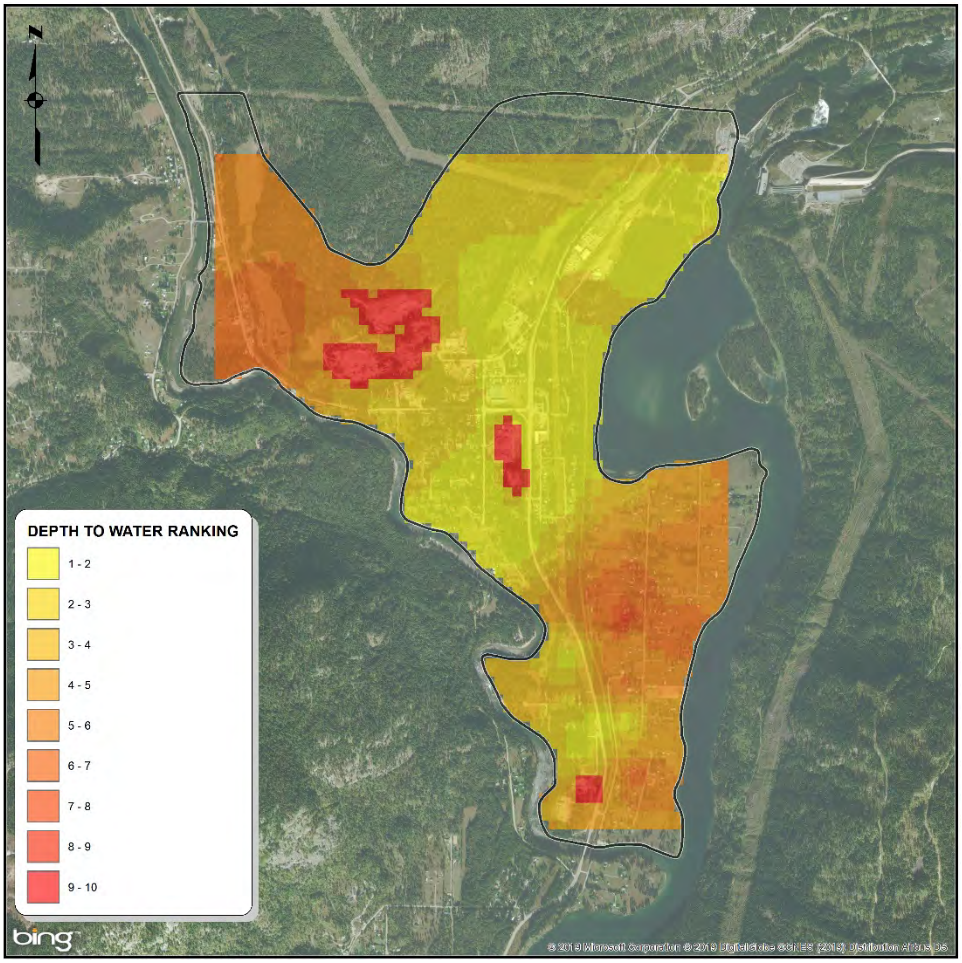

Figure 7. Drastic ranking of letter D, where a high ranking (red) represents a shallow depth to the water table.

Depth to groundwater is shallowest where there is expected to be the greatest interaction between the surface water (rivers) and the groundwater. Areas highlighted in red are the interpreted active or former aggregate operations.

4.2.2 R – NET RECHARGE

Net recharge of an aquifer is the volume of water reaching the aquifer over a specified period. As recharge to an aquifer increases, vulnerability increases, as downward movement of groundwater and potential contaminants is promoted. Recharge for an area is dependent on precipitation, temperature, geology, and vegetation.

In 2018, the Government of BC published a technical report relating to aquifer stress, groundwater recharge, and groundwater use for unconfined aquifers across BC (Forstner, 2018). Groundwater recharge within specific areas of British Colombia was mapped using two different models: Hydrologic Evaluation of Landfill Performance model (HELP) and PCRaster GLOBal Water Balance model (PCR-GLOBWB). The HELP model is designed to improve aquifer-scale estimates by generalisation of the major parameters of climate, based on Biogeoclimatic zones, and saturated hydraulic conductivity for soils, aquifer mapping, permeability, and mean water table depth. PCR-GLOBWB is a more complex global hydrological model. For this study area, HELP gives an average net recharge of 0.23 m/year, and PCR-GLOBWB gives an average value of 0.55 m/year.

Somewhere between these two given values is a reasonable estimate of the local net recharge. Recalculating 0.23 and 0.55 m/year to inches (units provided in DRASTIC method) gives an interval between 9 and 22 inches of net recharge per year. The DRASTIC rating is set to 10 when the net recharge is greater than 10 inches/year. If the true net recharge is somewhere between 9-22 inches, it is likely above 10 inches and the DRASTIC rating for R is set to 10 for the entire study area. No modifications were needed for the range and rating of this layer. The ArcGIS layer for R is presented on Figure 8.

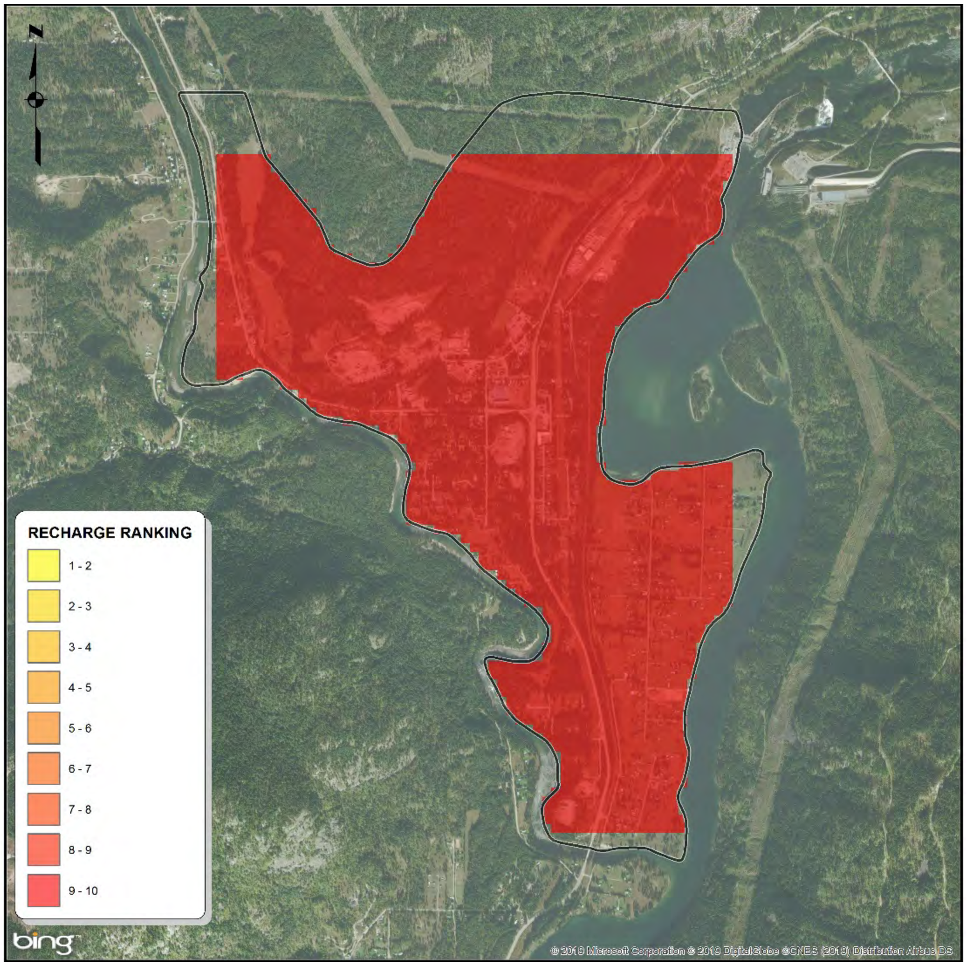

Figure 8. Ranking of letter R as it represents Net Recharge of greater than 10 inches/year (0.25 m/year) for the area.

4.2.3 A – AQUIFER MEDIA

The media of the aquifer describes what kind of geological material is present at the depth where a water well pumps from. If the aquifer is comprised of coarser material, it leads to higher vulnerability due to increased permeability and decreased attenuation time.

Review of the 80 available well logs produced a summary of the pumping depths and an assessment of the geological media that is present at the pumping depths. Where no screen depths for the well were available, it was assumed that the well is pumping from the base of the well.

In this case, the DRASTIC model only has one result that applies to the study area, which is for 'sand and gravel' ranked to 8. Most of the aquifer material in this study area consists of sand, coarse sand, sand and gravel, gravel, and coarse gravel. A more detailed Range-Rate table, to provide some variance within the study area, was setup for this parameter. The more detailed rating table is shown in Table 3.

Table 3. Range-Rate ranking for A

RANGE	RATE
Sand	7.5
Coarse Sand	7.8
Sand and Gravel	8
Sand and Boulders	8.5
Gravel	8.7
Coarse Gravel	9

As the aquifer information is only available at the water well locations, the 'A' rates were interpolated based on the known data points for the study area using the inverse distance method in ArcGIS and are presented on Figure 9.

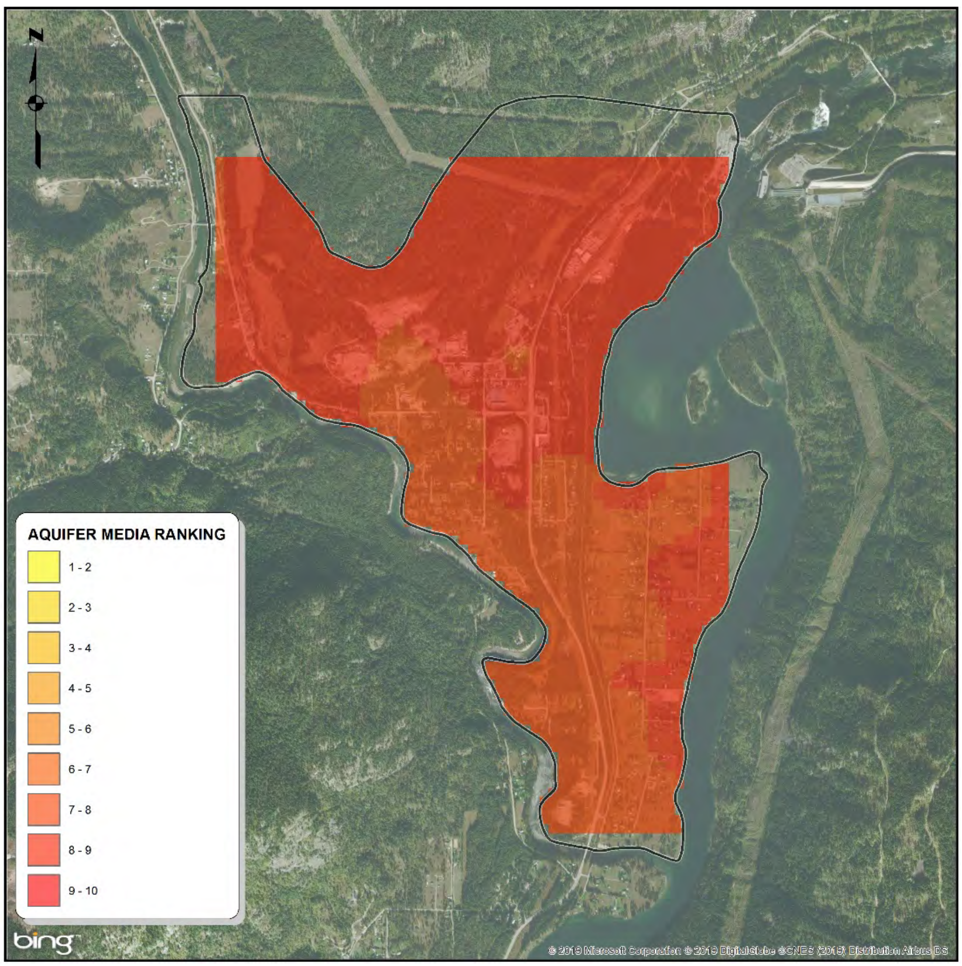

Figure 9. Ranking of letter A.

The aquifer media present in the study area has been assessed to be coarser grained in the northern portion and along the Kootenay River.

4.2.4 S – SOIL TEXTURE

The soil texture layer evaluates how resistant the top soil layers, the upper horizon (normally 2-3 m deep), is to preventing potential contamination from infiltrating further into the soil profile. Coarse textured soils or thin soils will have a higher vulnerability than fine textured soils, as water and potential contamination can move faster and the potential for natural attenuation is lower.

Soil mapping that includes information about soil texture, drainage, horizons, parent information, landform, and classification is available on iMapBC (Government BC, 2019). One of the available map layers shows the variance of soil texture within the study area. The layer was downloaded and the different texture classes were rated.

For the S layer, data is available for every single point of the study area and no interpolation is needed. Silty Loam and Sandy Loam match to DRASTIC ratings 4 and 6, respectively. Loamy Sand had no rating and was set to rating 8 after evaluating of the percent of sand, clay and silt in the different layers as per a soil textural classification chart. The soil texture variance and the S ratings are shown on Figure 10 and Figure 11, respectively.

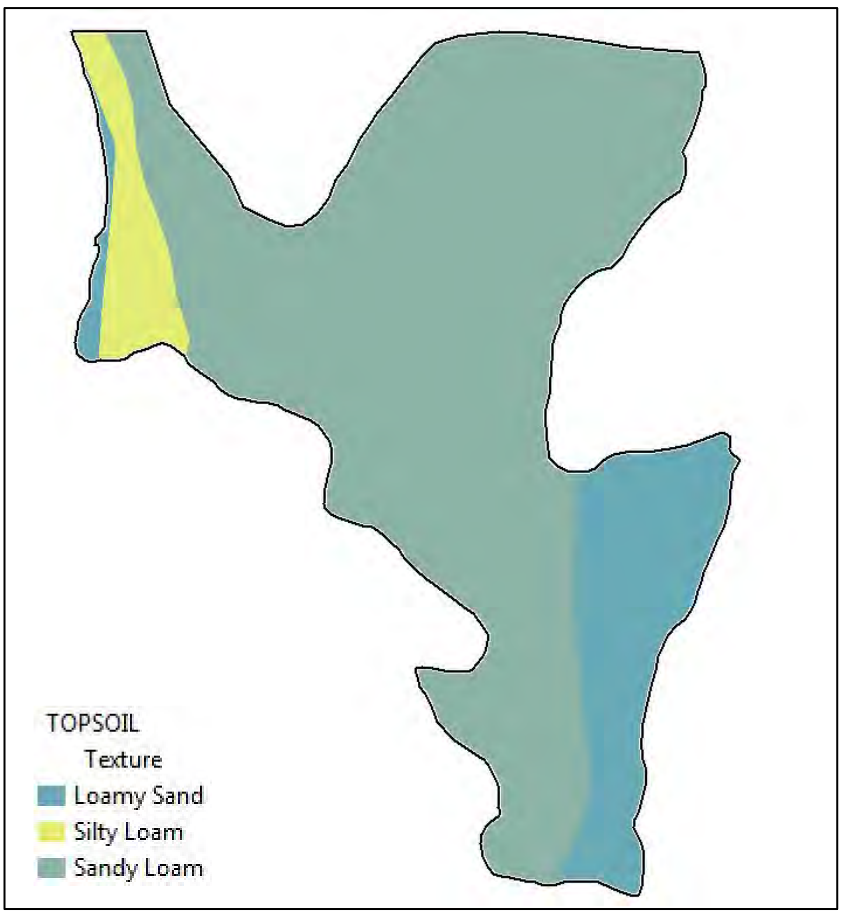

Figure 10. Soil Classification Map for the Study Area.

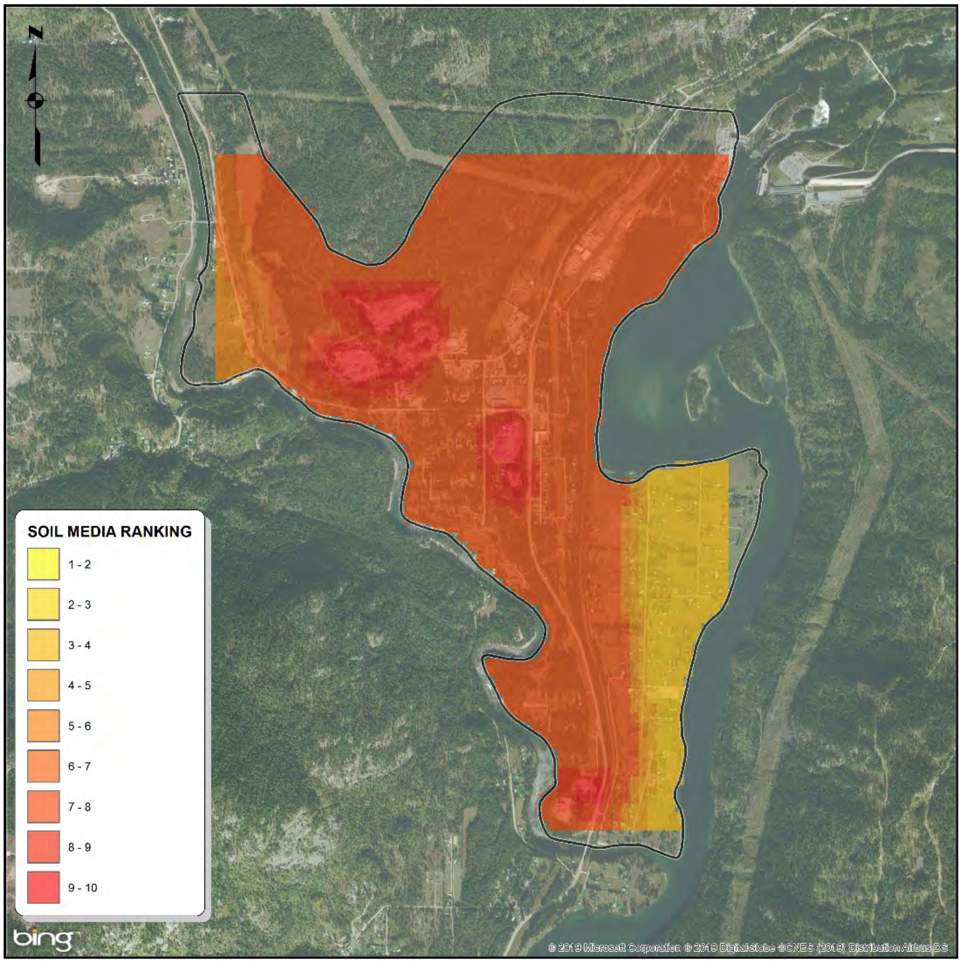

Figure 11. Ranking of letter S, which represent the soil texture in the model.

The soil media rankings were described above, and set based on the polygons available from iMapBC. Exceptions to this are the areas identified as active or former aggregate operations; those areas were set to a higher rating for the model.

4.2.5 T – TOPOGRAPHY

The topography of the ground surface is from a 25 m digital elevation model (DEM), which is of sufficient accuracy for this model. From the ArcGIS based DEM, the slope (%) can be calculated for every grid space throughout the study area using the topographic data. The DRATIC model ranks topography based on the slope percentage.

The DRASTIC values for ranges in slope are useable as laid out in the method, and no modification for the layer was required. The ArcGIS layer for letter T is presented on Figure 12.

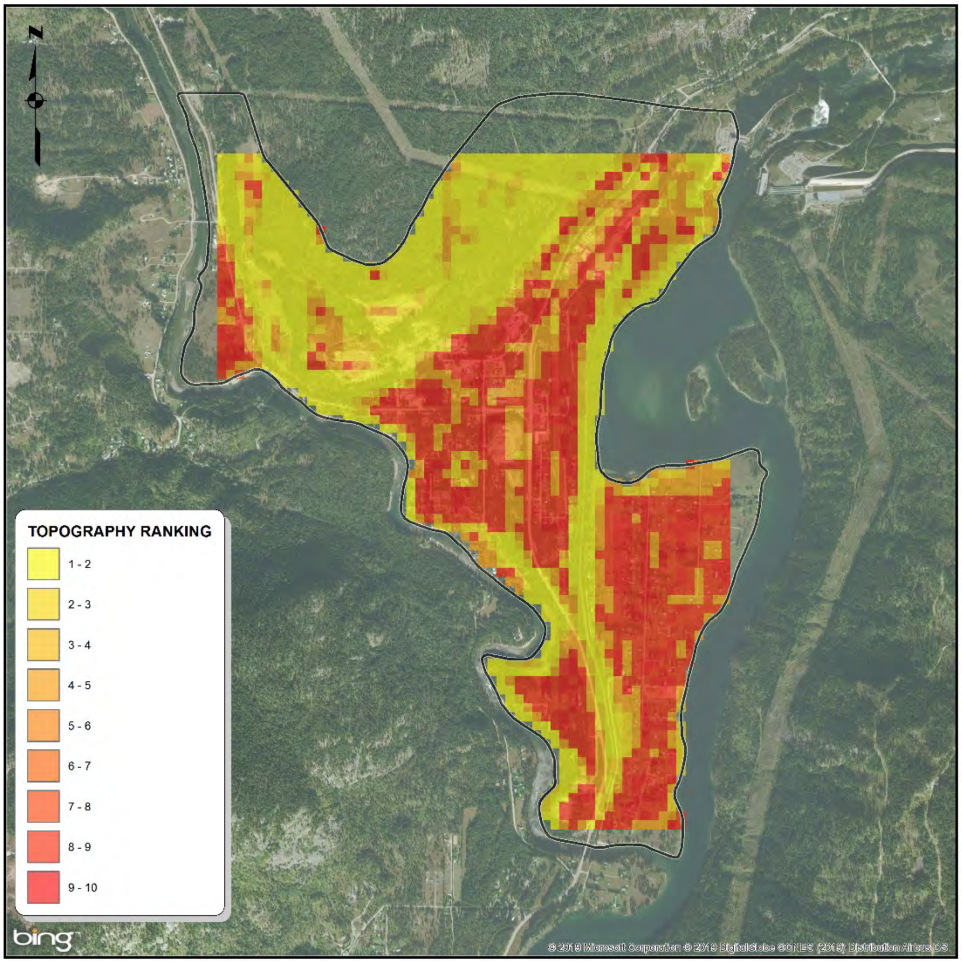

Figure 12. Ranking of letter T, representing the slope percentage based on topography.

Areas of higher slope promote runoff rather than infiltration of precipitation or runoff water and are less likely to have strong downward migration of surface water. Low slope areas will promote the downward flow of surface water into the groundwater system.

4.2.6 I – VADOZE ZONE

The vadose zone is the unsaturated area below the soil profile (A to C horizons – roughly estimated to be 1-2 m in thickness) and above the water table of the aquifer. Vulnerability of these materials is related to texture and permeability similar to other layers that assess lithology.

Review of the 64 available well logs with static water level data and lithology was completed to summarize the soil media of the vadose zone. Based on the lithology information, it is possible to fit the information into the DRASTIC model as presented. No adjustments to the data ranges and ranking was required.

As the information for the soil media in the vadose zone is only available at the water well locations, the 'I' rates were interpolated based on the known data points for the entire study area using the inverse distance method in ArcGIS. The ArcGIS layer for letter I is presented in Figure 13.

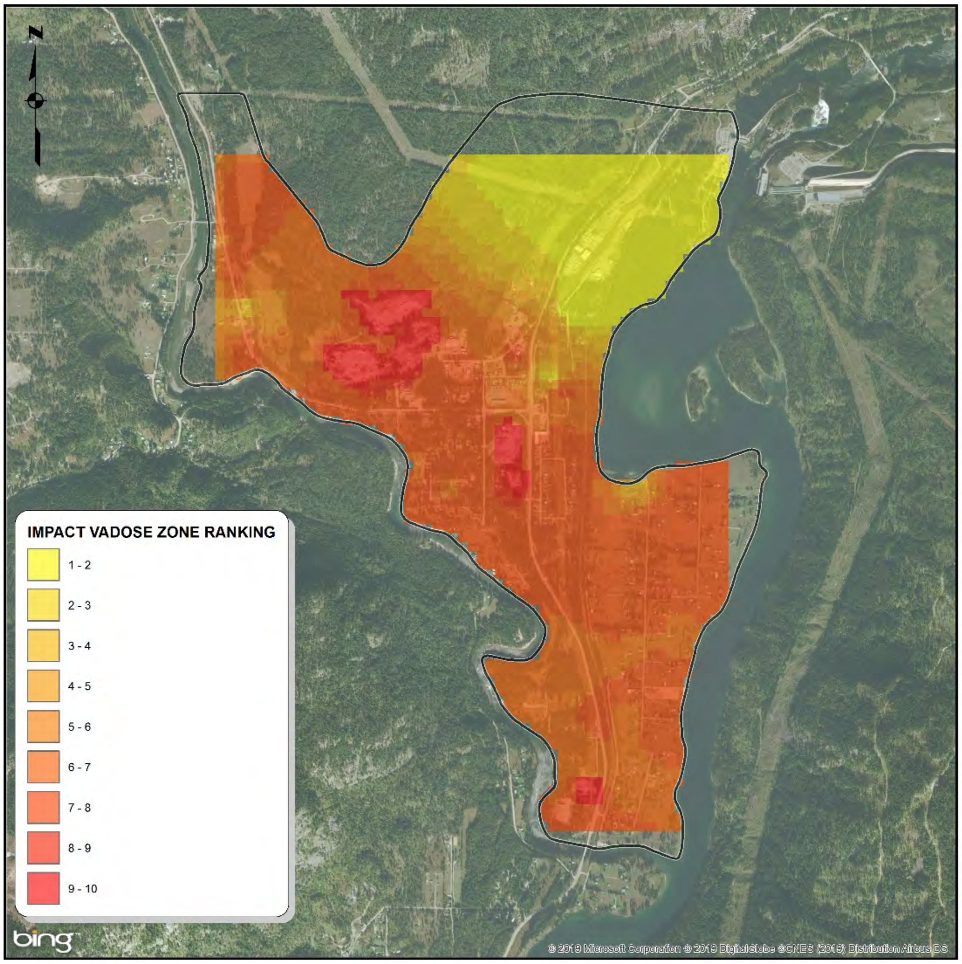

Figure 13. Ranking of letter I, representing the vulnerability of the vadose zone in the model.

Areas identified as active or former aggregate operations were set to a higher rating for the model as the vadose zone material will have been removed. The remaining areas were determined based on lithology data from water well records. The northeast corner of the model had finer-grained soil in the unsaturated vadose zone, as would be expected since this area was interpreted to be partially confined or confined.

4.2.7 C – HYDRAULIC CONDUCTIVITY

Hydraulic conductivity is the ability of an aquifer to transmit water, controlling the rate at which groundwater will flow under a given hydraulic gradient. Higher hydraulic conductivity values are observed in coarse-grained or fractured aquifers, leading to a higher vulnerability rating. Hydraulic conductivity is assessed within the aquifer and at the point where a well screen intersects the aquifer. Hydraulic conductivity values were estimated in two steps:

– Hydraulic conductivity can be estimated from the 2-hour pumping test data on water well records if drawdown is observed during the test. Only 10 of the 85 well records had enough drawdown data to estimate hydraulic conductivity values. The hydraulic conductivity values estimated based on the drawdown data all returned a DRASTIC rating of 10.

– Further review into the types of aquifer materials present in the study area allowed for an estimate of hydraulic conductivity values to be made based on published values and professional experience. This assessment provided a variance of the DRASTIC ratings for C to between 1, 2, and 10 for the water wells with no pumping data available.

As the information for the hydraulic conductivity is only available at the water well locations, the 'C' rates were interpolated based on the known data points for the entire study area using the inverse distance method in ArcGIS. The ArcGIS layer for letter C is presented on Figure 14.

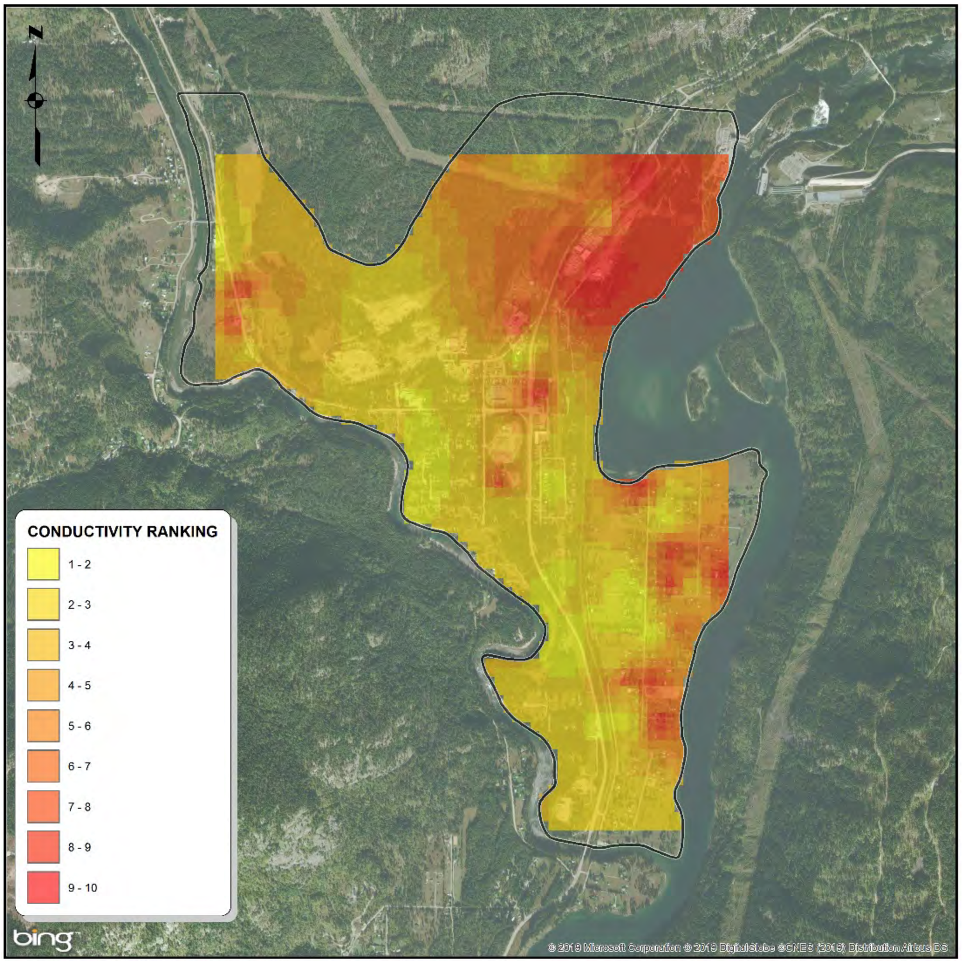

Figure 14. Ranking of letter C, representing the Hydraulic Conductivity within the aquifer of the grid space.

Hydraulic conductivity is related to the lithology of an aquifer, and higher conductivity values were identified in areas of coarser grained aquifer materials. Figures 9 and 14, representing letters C and A, show similar interpretations of the aquifer media.

4.3 VULNERABILTIY INDEX

Summarizing the DRASTIC ratings for each separate letter and calculating the final DRASTIC values using the weighted formula presented in the Methodology section, provides a single index for every 50 x 50 m grid square within the study area. The final values are presented on Figure 15. This map provides an overview of how vulnerable each portion of the study area is to potential pollution based on the local geological, hydrogeological, and physical conditions.

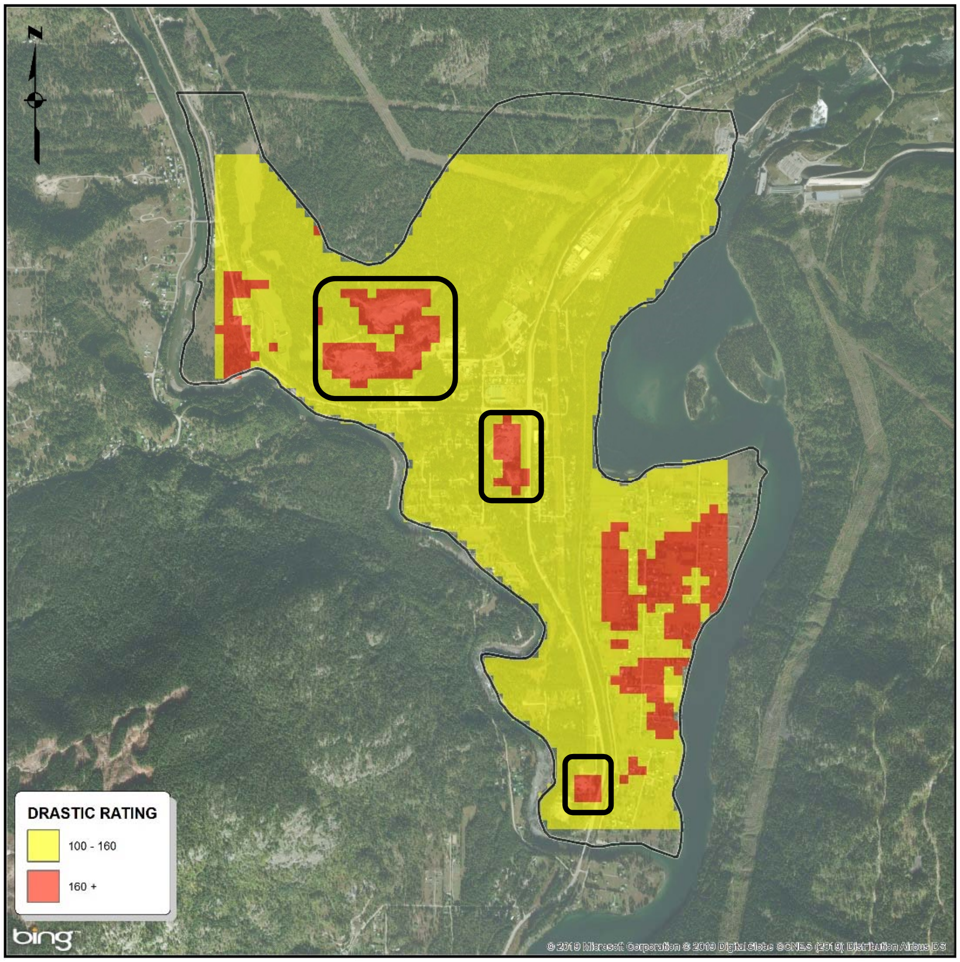

Figure 15. Final DRASTIC Vulnerability Index. Grey areas represent area with little to no data for analysis.

Yellow areas have a DRASTIC rating of 100 – 160, and are considered to be moderately vulnerable to groundwater contamination. Red areas have a DRASTIC rating of greater than 160, and are considered to be highly vulnerable to groundwater contamination. None of the mapped area, based on the DRASTIC model assumptions was mapped as ‘low vulnerability’. Most of the study area was determined to be of moderate vulnerability, and areas closest to the rivers or near aggregate operations show the highest vulnerability.

Areas outlined with black boxes have been assessed as some sort of aggregate operation, the removal of fine-grained soil materials has increased the vulnerability rating in these areas.

The vulnerability mapped for the majority of the Shoreacres subdivision is related primarily to the shallow groundwater, low land slope, and lack of fine-grained geological layers to protect the local aquifer.

5 CONCLUSIONS

The Shoreacres Aquifer (#0514) in the area of Playmor Junction is dominated by sand and gravels of fluvial and glaciofluvial origins. The confluence of the Slocan and Kootenay Rivers also means that the deposition of materials will have some deltaic properties. The nature of fluvial and deltaic depositional environments is that channels will have shifted and moved throughout the area during times of flooding and historical deposition, which means that coarse and fine-grained materials will be interbedded and discontinuous. The unconfined or partially confined nature of the lithological sequences observed in water well records highlights the variability of the historical depositional environment.

The DRASTIC Vulnerability Index was established to provide a broad ranking system for aquifers that are of high, medium, or low risk to contamination based on their geological, hydrogeological, and basic geographic properties. The DRASTIC Model was original designed for areas with greater variability in aquifer materials: however, this study was able to adapt the model in minor ways to reflect the local conditions.

The result of the DRASTIC assessment indicates that most of the study area is at some level of risk to contamination based on the physical properties of the aquifer and local geography. There are areas of higher risk that may require additional land-use planning to protect the aquifers and the local rivers to which they border. The rivers are expected to be regional groundwater discharge zones, so protection of local aquifers is also a factor in protecting local surface water quality.

Development within the high vulnerability areas (DRASTIC rating of 160+, mapped as red in Figure 15) needs to consider current density when additional development is proposed. Nutrient loading from existing and proposed septic fields or activities that remove fine-grained soil layers should be considered prior to issuing new development permits. Standards of development and level of wastewater treatment may need to be more stringent in these areas.

Development within the moderate vulnerability areas (DRASTIC rating of 100 – 160, mapped as yellow in Figure 15) may require additional assessment to determine the standards required for development. Additional assessments may include, but are not limited to; water well surveys, mapping local potential contaminant sources (such as septic fields), and assessing local groundwater flow direction to determine if there will be down-gradient receptors to a proposed development.

6 REFERENCES

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APPENDIX

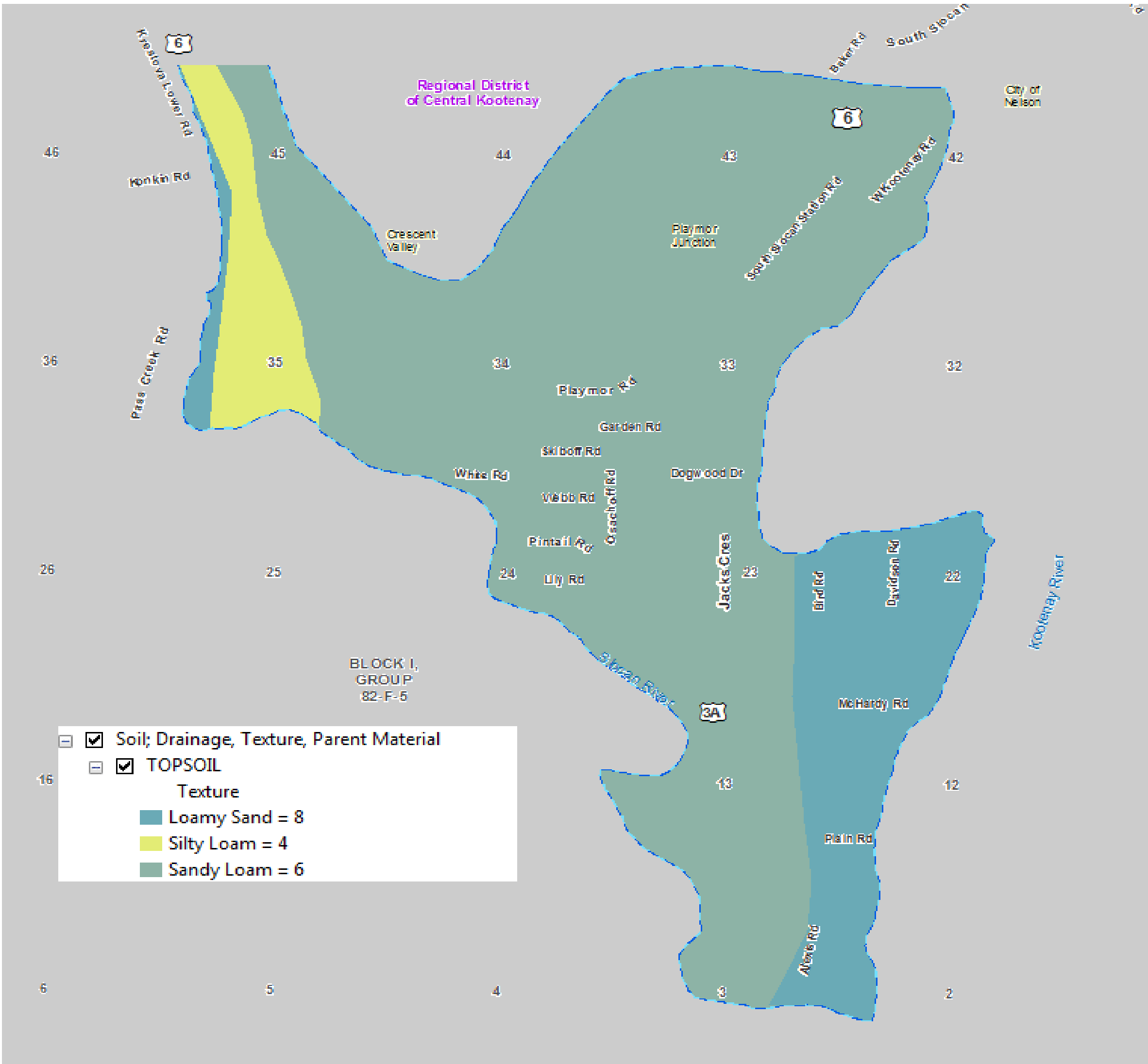
A INPUT DATA DRASTIC MODEL

Well ID	Confined or Unconfined	Depth to Static Water Level (ft)	Depth to Confined Layer (ft)	Drastic Rating for 'D'
74620	Unconfined	12		9
74621	Unconfined	18		7
66298	Unconfined	20		7
16124	Unconfined	22		7
21601	Unconfined	25		7
16566	Unconfined	26		7
88501	Unconfined	27		7
88636	Unconfined	28		7
56072	Unconfined	30		7
74622	Unconfined	30		7
85987	Unconfined	30		7
86190	Unconfined	30		7
74617	Unconfined	32		5
85989	Unconfined	32		5
58242	Unconfined	33		5
85958	Unconfined	33		5
85914	Unconfined	34		5
74626	Unconfined	35		5
20861	Unconfined	37		5
90301	Unconfined	39		5
91690	Unconfined	39		5
31146	Unconfined	40		5
407	Unconfined	41		5
16125	Unconfined	42		5
88505	Unconfined	42		5
19195	Unconfined	43		5
87996	Unconfined	43		5
27917	Unconfined	52		3
56250	Unconfined	58		3
43622	Unconfined	69		3
48574	Unconfined	73		3
57587	Unconfined	75		3
66396	Unconfined	75		3
91907	Unconfined	84		2
57567	Unconfined	85		2
57576	Unconfined	85		2
405	Unconfined	90		2
406	Unconfined	103		1
23926	Unconfined	104		1
32162	Unconfined	106		1
53131	Unconfined	110		1
74618	Unconfined	110		1
48385	Unconfined	120		1
34533	Unconfined	125		1
49469	Unconfined	132		1
86314	Unconfined	140		1
71635	Unconfined	150		1
66190	Unconfined	170		1
47916	Unconfined	179		1
43261	Unconfined	182		1
41052	Unconfined	184		1
82081	Confined		84	2
71636	Confined		60	3
66320	Confined		152	1
58516	Confined		65	3
90304	Confined		-	-

Area	Drastic Rating for 'R'
Entire area	10

Well ID	Lithology of Aquifer Material	Drastic Rating for 'A'
86190	Fine Sand	7
86190	Fine Sand	7
406	Fine Sand	7
19195	Fine Sand	7
71635	Fine Sand	7
91690	Fine Sand	7
91907	Fine Sand	7
81730	Fine Sand	7
82177	Fine Sand	7
82181	Fine Sand	7
82181	Fine Sand	7
81729	Fine Sand	7
23926	Sand	7.5
48385	Sand	7.5
66298	Sand	7.5
66297	Sand	7.5
74620	Sand	7.5
74621	Sand	7.5
57569	Coarse Sand	7.8
43261	Coarse Sand	7.8
49469	Coarse Sand	7.8
82175	Sand and Gravel	8
48574	Sand and Gravel	8
85987	Sand and Gravel	8
85987	Sand and Gravel	8
90304	Sand and Gravel	8
90304	Sand and Gravel	8
90304	Sand and Gravel	8
94498	Sand and Gravel	8
94517	Sand and Gravel	8
16566	Sand and Gravel	8
87996	Sand and Gravel	8
32162	Sand and Gravel	8
53131	Sand and Gravel	8
56250	Sand and Gravel	8
58242	Sand and Gravel	8
66396	Sand and Gravel	8
71636	Sand and Gravel	8
405	Sand and Gravel	8
407	Sand and Gravel	8
16124	Sand and Gravel	8
16125	Sand and Gravel	8
31146	Sand and Gravel	8
34533	sand and gravel	8
43622	sand and gravel	8
56754	Sand and Gravel	8
57567	Sand and Gravel	8
57576	Sand and Gravel	8
57587	Sand and Gravel	8
66190	Sand and Gravel	8
74617	Sand and Gravel	8
74618	Sand and Gravel	8
74619	Sand and Gravel	8
74626	Sand and Gravel	8
56072	Sand and Gravel	8
81728	Sand and Gravel	8
58516	Silty Gravel	8.5
29232	Silty Gravel	8.5
82080	Silty Gravel	8.5
82176	Silty Gravel	8.5
19240	Sand and Boulders	8.5
82081	Gravel	8.7
47916	Gravel	8.7
21601	Gravel	8.7
27917	Gravel	8.7
66290	Coarse Gravel	9
85914	Coarse Gravel	9
85914	Coarse Gravel	9
85989	Coarse Gravel	9
85989	Coarse Gravel	9
90304	Coarse Gravel	9
79312	Coarse Gravel	9
88505	Coarse Gravel	9
88501	Coarse Gravel	9
82170	Coarse Gravel	9
85958	Coarse Gravel	9
85958	Coarse Gravel	9
66320	Pea Gravel	9
90301	Pea Gravel	9
20861	Gravel and Boulders	9
74622	Boulders	9

Topsoil Layer	Drastic Rating for 'S'
Loamy Sand	8
Sandy Loam	6
Silty Loaam	4



Well ID	Slope (%)	Drastic Rating for 'T'
66298	0.3	10
66190	0.6	10
88426	0.7	10
94473	0.9	10
16124	1.1	10
94459	1.1	10
88636	1.4	10
406	1.4	10
86190	1.4	10
94551	1.7	10
31146	1.8	10
94551	1.8	10
48385	1.9	10
85958	2.0	10
91907	2.1	10
94535	2.2	10
43622	2.3	10
47916	2.5	9
74619	2.5	9
88505	2.5	9
81729	2.6	9
53131	2.9	9
19195	2.9	9
90301	3.0	9
20861	3.1	9
86314	3.1	9
48574	3.1	9
74626	3.1	9
66297	3.1	9
74618	3.2	9
94498	3.3	9
85914	3.3	9
58242	3.5	9
85989	3.5	9
94551	3.6	9
82181	3.6	9
29232	3.6	9
58516	3.6	9
82081	4.1	9
16566	4.4	9
56250	4.5	9
74620	4.6	9
79312	4.7	9
94551	4.7	9
94551	4.8	9
407	4.8	9
94551	4.9	9
74617	5.4	9
82170	5.4	9
43261	5.4	9
49469	5.4	9
91690	5.5	9
94551	5.6	9
21601	5.7	9
94450	5.7	9
34533	5.9	9
88501	6.1	9
82175	6.6	5
41052	6.6	5
66290	6.6	5
94517	6.7	5
32162	6.9	5
82079	7.0	5
56072	7.2	5
94551	7.2	5
57567	7.4	5
66320	7.4	5
81730	7.9	5
57569	8.1	5
56754	8.1	5
90304	8.1	5
88640	8.8	5
71635	9.6	5
74622	9.7	5
82177	9.8	5
57587	10.4	5
87996	10.4	5
23926	11.5	5
82080	12.7	3
85987	13.4	3
16125	13.6	3
94551	13.9	3
19240	14.8	3
27917	17.1	3
57576	17.2	3
66396	23.5	1
82176	25.6	1
405	28.7	1
91904	30.8	1
81728	30.9	1
71636	32.4	1
94534	34.8	1
74621	43.8	1

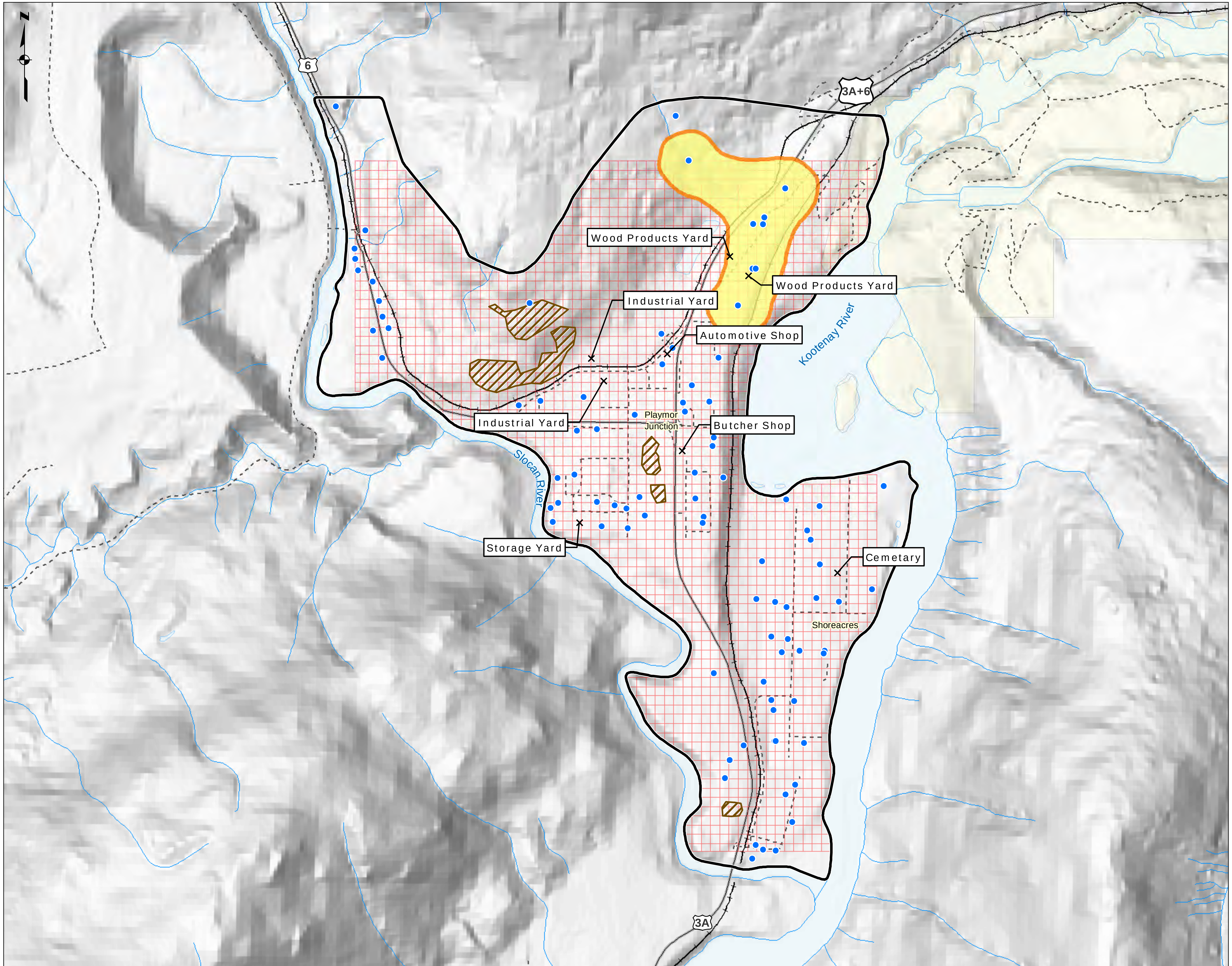
Reference Chart for all Grid Cells	
Slope (%)	Rating
0.0	10
1.0	10
2.0	10
2.5	9
3.0	9
4.0	9
5.0	9
6.0	9
6.5	5
7.0	5
8.0	5
9.0	5
10.0	5
11.0	5
12.0	5
12.5	3
13.0	3
14.0	3
15.0	3
16.0	3
17.9	3
18.0	1

Well ID	Confined or Unconfined	Material in Vadoze Zone	Drastic Rating for 'I'
405	unconfined	Sand and Gravel	8
406	unconfined	Sand and Gravel	8
407	unconfined	Sand and Gravel	8
16124	unconfined	Sand and Gravel	8
16125	unconfined	Sand and Gravel with Significant Silt and Clay	6
16566	unconfined	Clay	1
19195	unconfined	Sand and Gravel	8
20861	unconfined	Sand and Gravel	8
21601	unconfined	Sand and Gravel	8
23926	unconfined	Sand and Gravel	8
27917	unconfined	Silt	3
31146	unconfined	Sand and Gravel	8
32162	unconfined	Sand and Gravel with Significant Silt and Clay	6
34533	unconfined	Sand and Gravel	8
41052	unconfined	Sand and Gravel	8
43261	unconfined	Sand and Gravel	8
43622	unconfined	Sand and Gravel	8
47916	unconfined	Sand and Gravel with Significant Silt and Clay	6
48385	unconfined	Sand and Gravel with Significant Silt and Clay	6
48574	unconfined	Sand and Gravel	8
49469	unconfined	Sand and Gravel	8
53131	unconfined	Sand and Gravel	8
56072	unconfined	Sand and Gravel with Significant Silt and Clay	6
56250	unconfined	Sand and Gravel	8
56754	unconfined	Sand and Gravel	8
57567	unconfined	Sand and Gravel	8
57576	unconfined	Sand and Gravel	8
57587	unconfined	Sand and Gravel	8
58242	unconfined	Sand and Gravel with Significant Silt and Clay	6
66190	unconfined	Sand and Gravel	8
66298	unconfined	Sand and Gravel	8
66396	unconfined	Sand and Gravel with Significant Silt and Clay	6
71635	unconfined	Sand and Gravel with Significant Silt and Clay	6
74617	unconfined	Sand and Gravel with Significant Silt and Clay	6
74618	unconfined	Sand and Gravel with Significant Silt and Clay	6
74620	unconfined	Sand and Gravel	8
74621	unconfined	Silt	3
74622	unconfined	Sand and Gravel	8
74626	unconfined	Sand and Gravel with Significant Silt and Clay	6
79312	unconfined	Sand and Gravel	8
85914	unconfined	Sand and Gravel	8
85958	unconfined	Sand and Gravel	8
85987	unconfined	Sand and Gravel	8
85989	unconfined	Sand and Gravel	8
86190	unconfined	Sand and Gravel	8
86314	unconfined	Sand and Gravel with Significant Silt and Clay	6
87996	unconfined	Sand and Gravel	8
88426	unconfined	Sand and Gravel	8
88501	unconfined	Sand and Gravel with Significant Silt and Clay	6
88505	unconfined	Sand and Gravel	8
90301	unconfined	Sand and Gravel	8
91690	unconfined	Sand and Gravel	8
91904	unconfined	Sand and Gravel	8
91907	unconfined	Sand and Gravel	8
94459	unconfined	Clay	1
58516	confined	Sand and Gravel with Significant Silt and Clay	1
90304	confined	Sand and Gravel	1
71636	confined	Sand and Gravel with Significant Silt and Clay	1
66290	confined	Sand and Gravel	1
66320	confined	Sand and Gravel with Significant Silt and Clay	1

Well Tag ID	Lithology Aquifer	Estimated K (m/s)	Updated K (gpd/ft^2)	Drastic Rating for 'C'
86190	Fine Sand	1.00E-06	2.12	1
86190	Fine Sand	1.00E-06	2.12	1
406	Fine Sand	1.00E-06	2.12	1
19195	Fine Sand	1.00E-06	2.12	1
71635	Fine Sand	1.00E-06	2.12	1
91690	Fine Sand	1.00E-06	2.12	1
91907	Fine Sand	1.00E-06	2.12	1
81730	Fine Sand	1.00E-06	2.12	1
82177	Fine Sand	1.00E-06	2.12	1
82181	Fine Sand	1.00E-06	2.12	1
82181	Fine Sand	1.00E-06	2.12	1
81729	Fine Sand	1.00E-06	2.12	1
23926	Sand	1.00E-05	21.2	1
48385	Sand	1.00E-05	21.2	1
66298	Sand	1.00E-05	21.2	1
66297	Sand	1.00E-05	21.2	1
74620	Sand	1.00E-05	21.2	1
74621	Sand	1.00E-05	21.2	1
57569	Coarse Sand	1.00E-05	21.2	1
43261	Coarse Sand	1.00E-05	21.2	1
49469	Coarse Sand	1.00E-05	21.2	1
82175	Sand and Gravel	1.00E-04	212	2
48574	Sand and Gravel	1.00E-04	212	2
85987	Sand and Gravel	1.00E-04	212	2
85987	Sand and Gravel	1.00E-04	212	2
90304	Sand and Gravel	1.00E-04	212	2
90304	Sand and Gravel	1.00E-04	212	2
90304	Sand and Gravel	1.00E-04	212	2
94498	Sand and Gravel	1.00E-04	212	2
94517	Sand and Gravel	1.00E-04	212	2
16566	Sand and Gravel	1.00E-04	212	2
87996	Sand and Gravel	1.00E-04	212	2
32162	Sand and Gravel	1.00E-04	212	2
53131	Sand and Gravel	1.00E-04	212	2
56250	Sand and Gravel	1.00E-04	212	2
58242	Sand and Gravel	1.00E-04	212	2
66396	Sand and Gravel	1.00E-04	212	2
71636	Sand and Gravel	1.00E-04	212	2
405	Sand and Gravel	1.00E-04	212	2
407	Sand and Gravel	1.00E-04	212	2
16124	Sand and Gravel	1.00E-04	212	2
16125	Sand and Gravel	1.00E-04	212	2
31146	Sand and Gravel	1.00E-04	212	2
34533	sand and gravel	1.00E-04	212	2
43622	sand and gravel	1.00E-04	212	2
56754	Sand and Gravel	1.00E-04	212	2
57567	Sand and Gravel	1.00E-04	212	2
57576	Sand and Gravel	1.00E-04	212	2
57587	Sand and Gravel	1.00E-04	212	2
66190	Sand and Gravel	1.00E-04	212	2
74617	Sand and Gravel	1.00E-04	212	2
74618	Sand and Gravel	1.00E-04	212	2
74619	Sand and Gravel	1.00E-04	212	2
74626	Sand and Gravel	1.00E-04	212	2
56072	Sand and Gravel	1.00E-04	212	2
81728	Sand and Gravel	1.00E-04	212	2
58516	Silty Gravel	1.00E-03	2120	10
29232	Silty Gravel	1.00E-03	2120	10
82080	Silty Gravel	1.00E-03	2120	10
82176	Silty Gravel	1.00E-03	2120	10
19240	Sand and Boulders	1.00E-03	2120	10
82081	Gravel	1.00E-02	21200	10
47916	Gravel	1.00E-02	21200	10
21601	Gravel	1.00E-02	21200	10
27917	Gravel	1.00E-02	21200	10
66290	Coarse Gravel	1.00E-02	21200	10
85914	Coarse Gravel	1.00E-02	21200	10
85914	Coarse Gravel	1.00E-02	21200	10
85989	Coarse Gravel	1.00E-02	21200	10
85989	Coarse Gravel	1.00E-02	21200	10
90304	Coarse Gravel	1.00E-02	21200	10
79312	Coarse Gravel	1.00E-02	21200	10
88505	Coarse Gravel	1.00E-02	21200	10
88501	Coarse Gravel	1.00E-02	21200	10
82170	Coarse Gravel	1.00E-02	21200	10
85958	Coarse Gravel	1.00E-02	21200	10
85958	Coarse Gravel	1.00E-02	21200	10
66320	Pea Gravel	1.00E-02	21200	10
90301	Pea Gravel	1.00E-02	21200	10
20861	Gravel and Boulders	1.00E-02	21200	10
74622	Boulders	1.00E-02	21200	10

APPENDIX

B MAPS



Legend

- Potential Concerns
- Water Well Location
- Gravel Pit
- Study Area
- Interpreted Confined Area of the Aquifer
- 50 x 50 m Evaluation Grid
- Highway
- Paved Road
- Train Track
- Municipalities
- River/Creek
- River/Lake

Site Overview

Shoreacres Aquifer

Playmor Junction, British Columbia

Scale: 1:20,000

0 0.2 0.4 0.6 0.8 1 Km

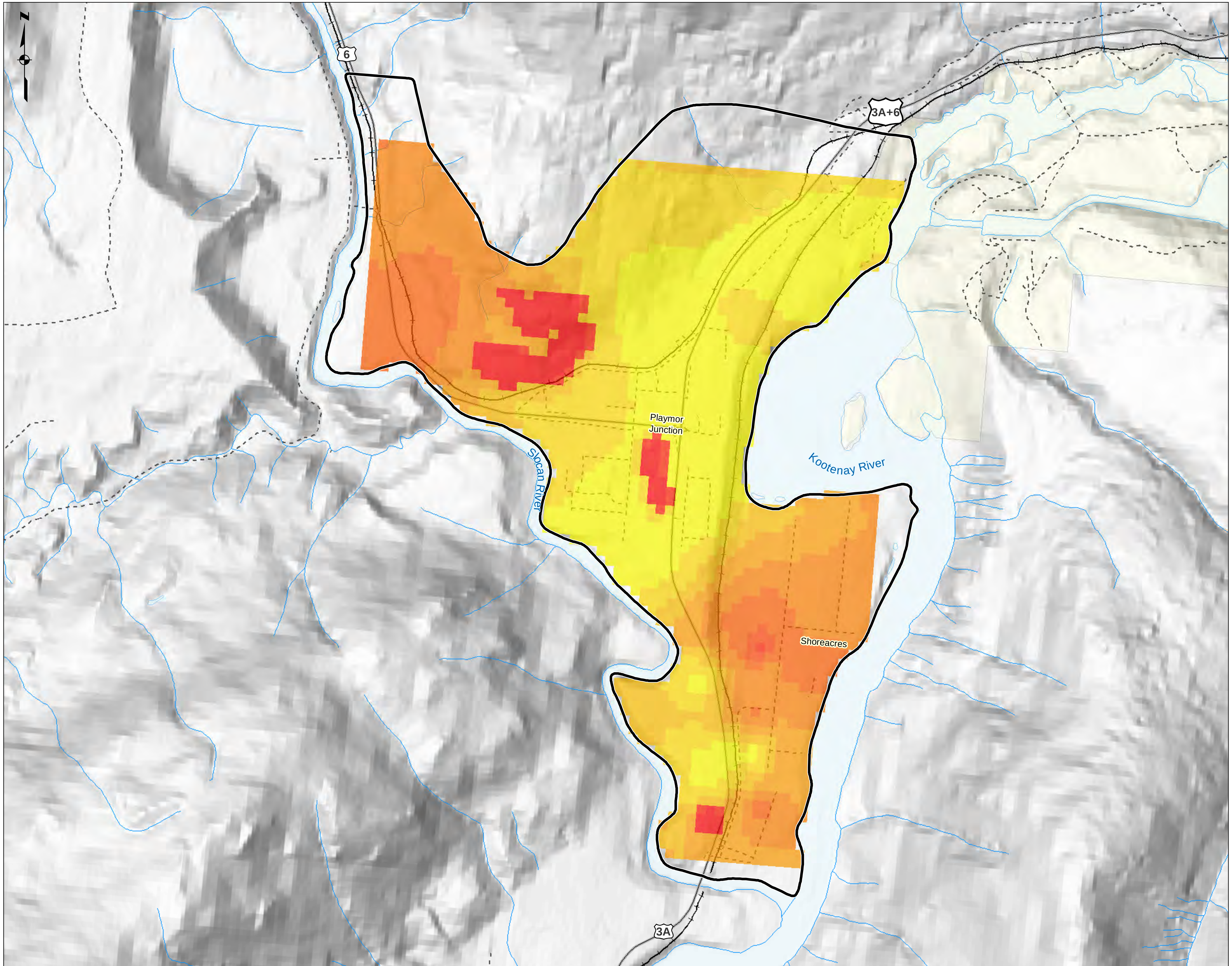
Universal Transverse Mercator (Zone 10)

North American Datum (1983)

Report By: AB
Drawn by: AN
Reviewed By: AB

WSP Job #: 191-01666-00
Date: May 2, 2019
Office: Edmonton

Notes:Imagery Source: ESRI IMagery Service

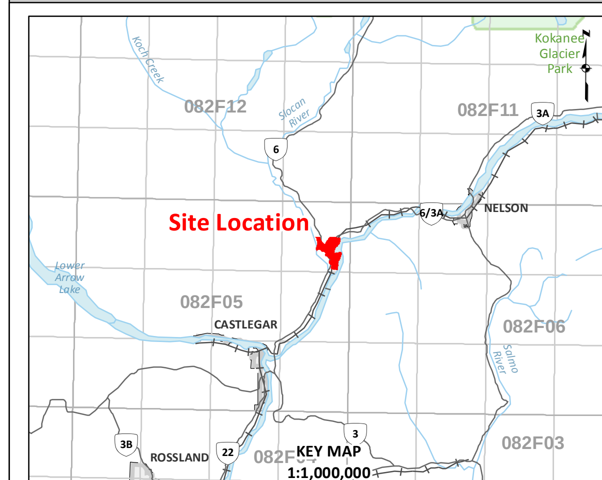


Legend

- Study Area
- Highway
- Paved Road
- Train Track
- Municipalities
- River/Creek
- River/Lake

Depth to Water Rating

- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10

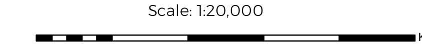


DRASTIC Ranking of Letter D (Depth to Water)

Shoreacres Aquifer

Playmor Junction, British Columbia

Scale: 1:20,000

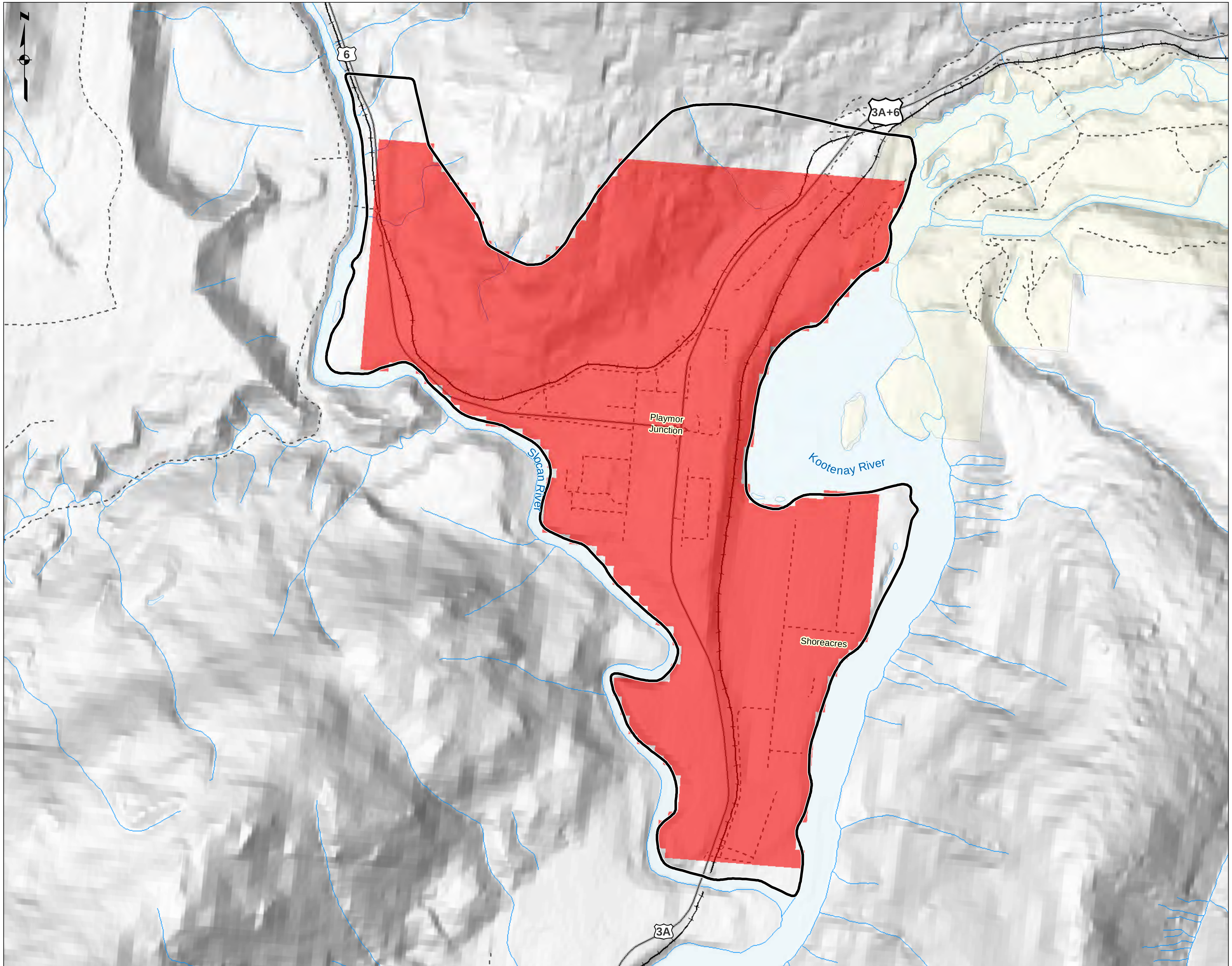


Universal Transverse Mercator (Zone 10)
North American Datum (1983)

Report By: AB
Drawn by: AN
Reviewed By: AB

WSP Job #: 191-01666-00
Date: May 2, 2019
Office: Edmonton

Notes:Imagery Source: ESRI IMagery Service

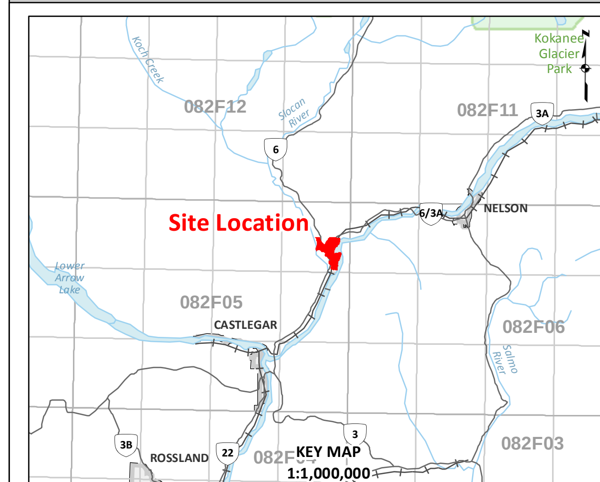


Legend

- Study Area
- Highway
- Paved Road
- Train Track
- Municipalities
- River/Creek
- River/Lake

Recharge Rating

- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10



DRASTIC Ranking Of Letter R (Net Recharge)

Shoreacres Aquifer

Playmor Junction, British Columbia

Scale: 1:20,000

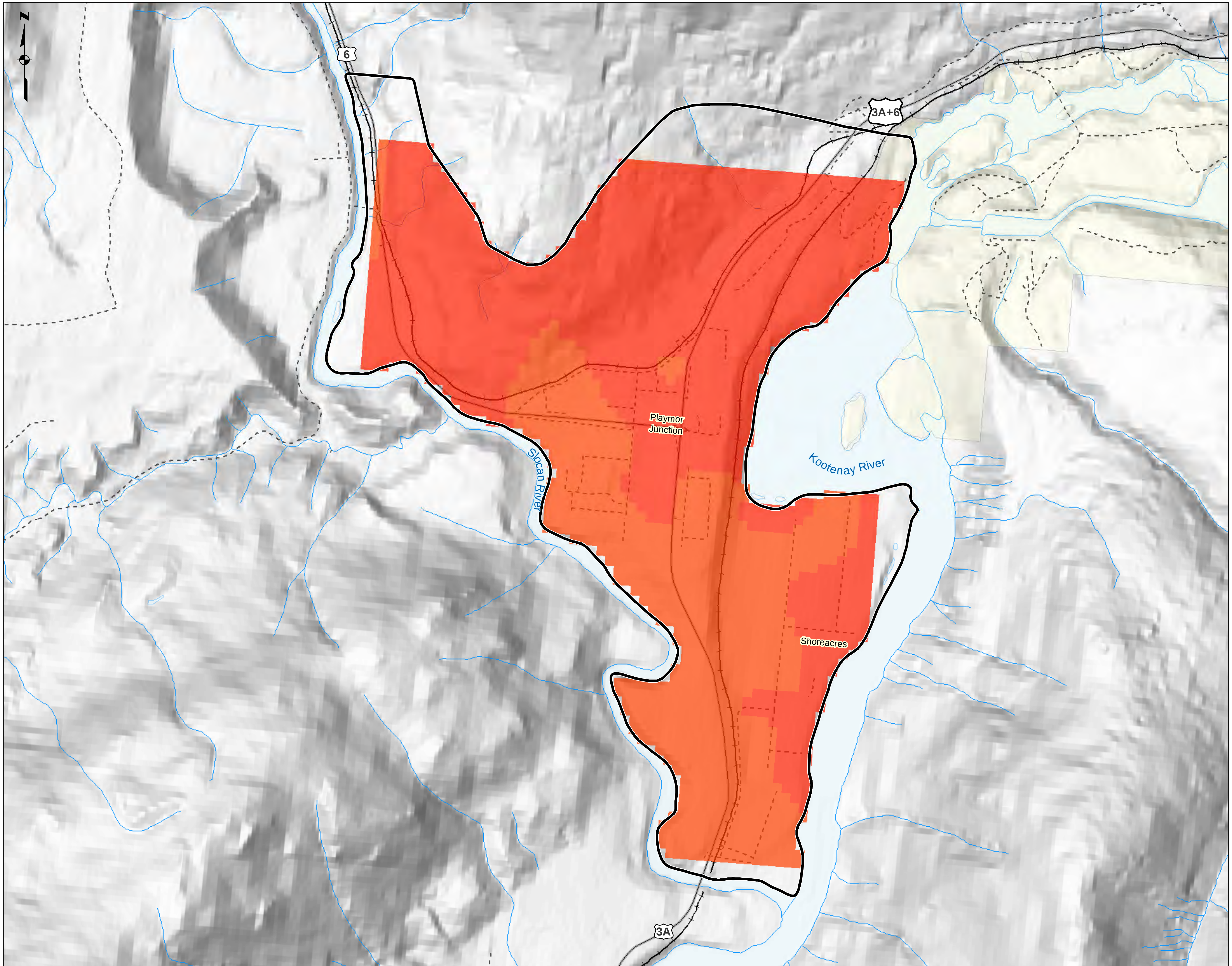
0 0.2 0.4 0.6 0.8 1 Km

Universal Transverse Mercator (Zone 10)
North American Datum (1983)

Report By: AB
Drawn by: AN
Reviewed By: AB

WSP Job #: 191-01666-00
Date: May 2, 2019
Office: Edmonton

Notes: Imagery Source: ESRI IMagery Service

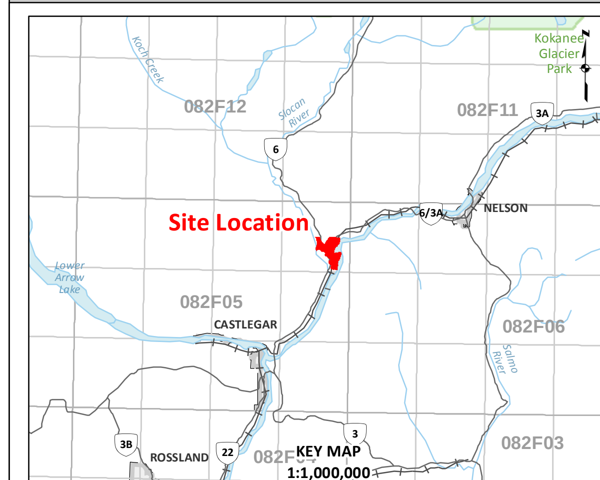


Legend

- Study Area
- Highway
- Paved Road
- Train Track
- Municipalities
- River/Creek
- River/Lake

Aquifer Media Rating

- 1 - 2
- 2-3
- 3-4
- 4-5
- 5-6
- 6-7
- 7-8
- 8-9
- 9-10



DRASTIC Ranking of Letter A (Aquifer Media)

Shoreacres Aquifer

Playmor Junction, British Columbia

Scale: 1:20,000

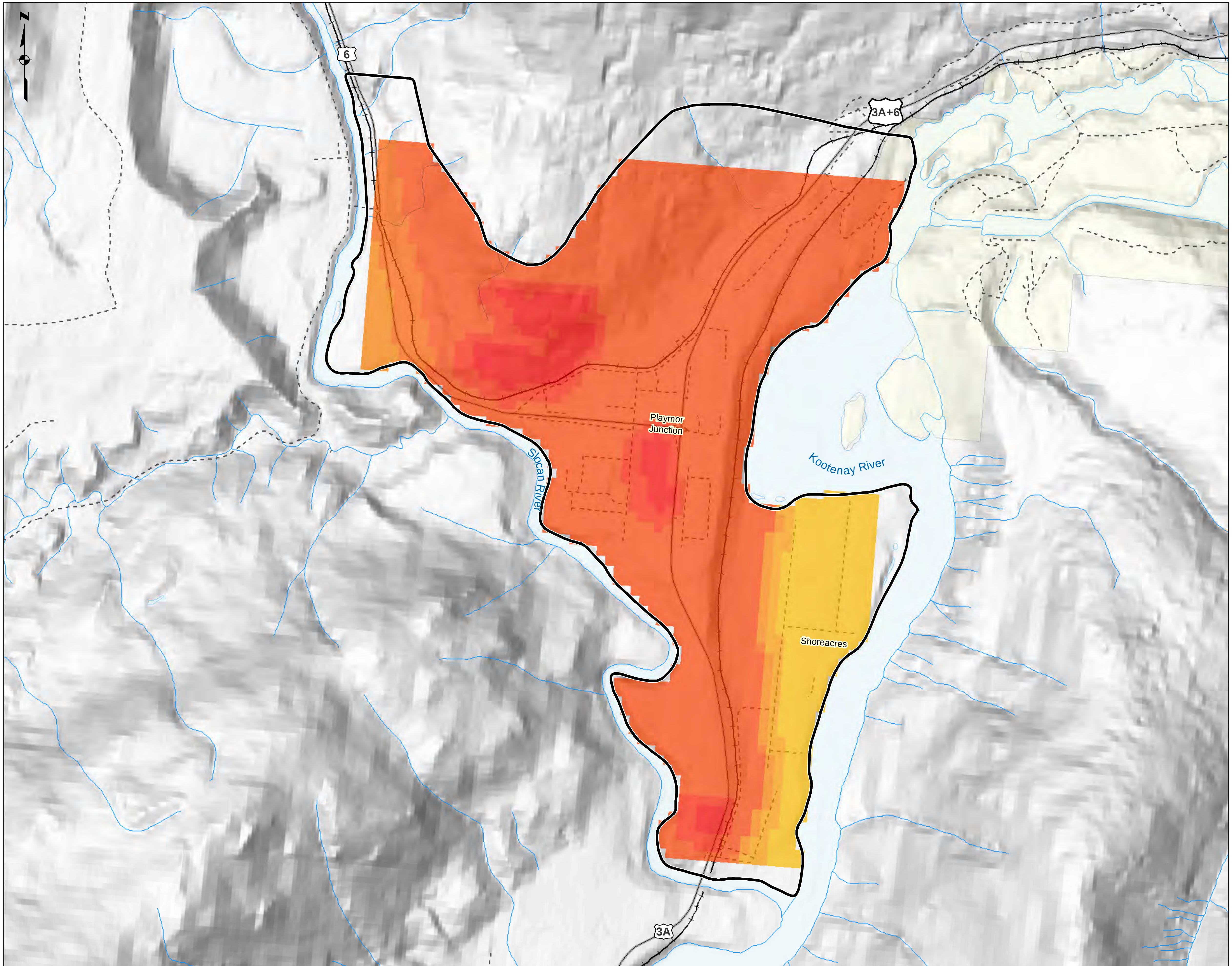
0 0.2 0.4 0.6 0.8 1 Km

Universal Transverse Mercator (Zone 10)
North American Datum (1983)

Report By: AB
Drawn by: AN
Reviewed By: AB

WSP Job #: 191-01666-00
Date: May 2, 2019
Office: Edmonton

Notes:Imagery Source: ESRI IMagery Service

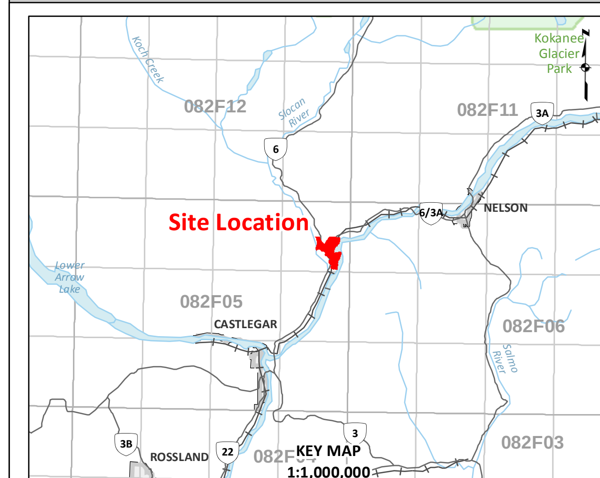


Legend

- Study Area
- Highway
- Paved Road
- Train Track
- Municipalities
- River/Creek
- River/Lake

Soil Media Rating

- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10



DRASTIC Ranking of Letter S (Soil Media)

Shoreacres Aquifer

Playmor Junction, British Columbia

Scale: 1:20,000

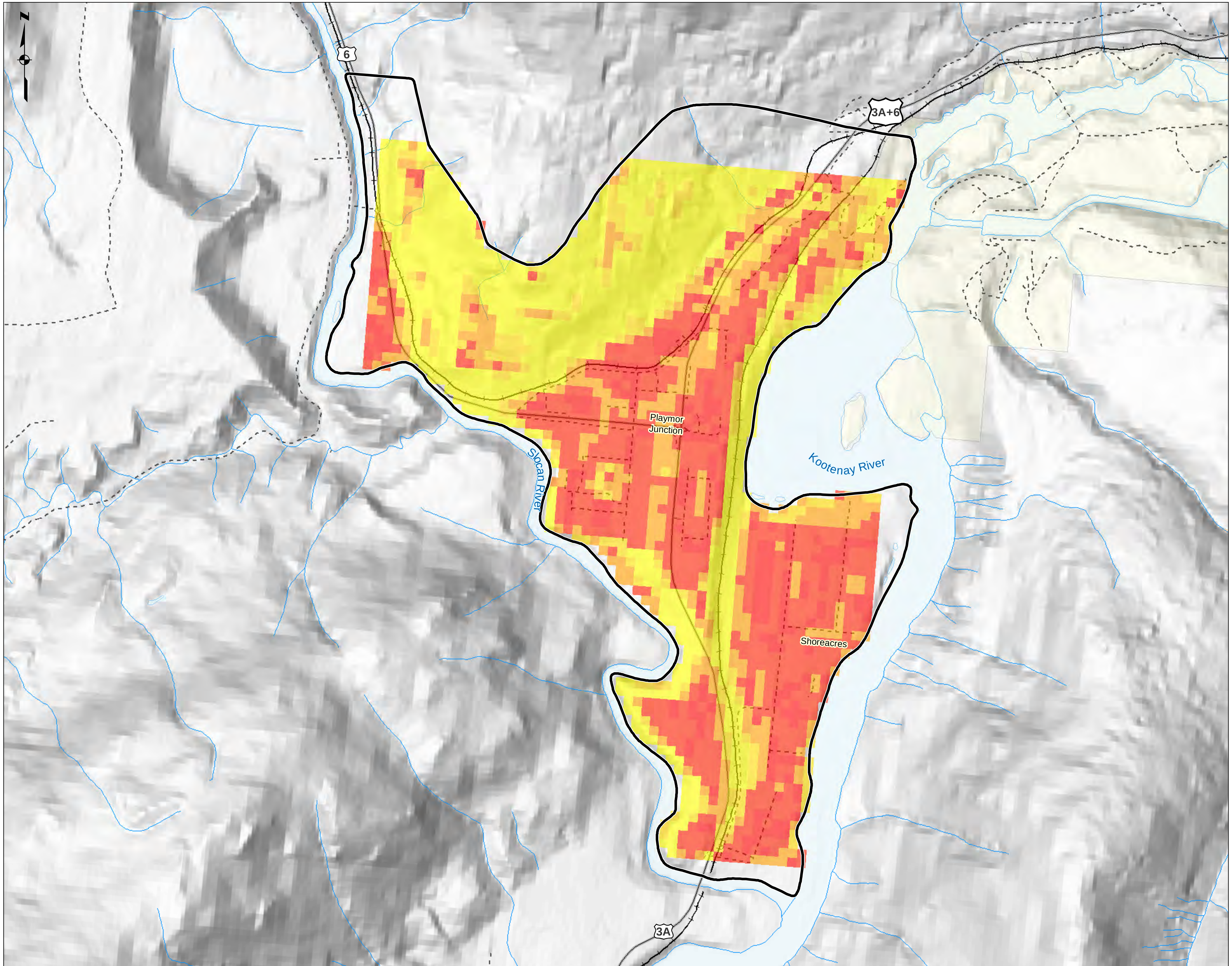
0 0.2 0.4 0.6 0.8 1 Km

Universal Transverse Mercator (Zone 10)
North American Datum (1983)

Report By: AB
Drawn by: AN
Reviewed By: AB

WSP Job #: 191-01666-00
Date: May 2, 2019
Office: Edmonton

Notes:Imagery Source: ESRI IMagery Service

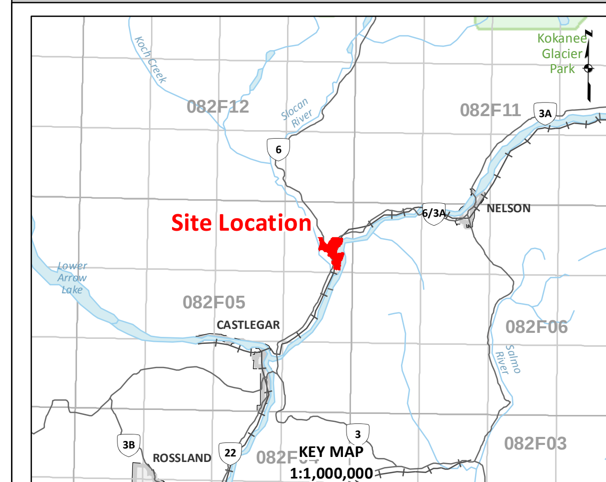


Legend

- Study Area
- Highway
- Paved Road
- Train Track
- Municipalities
- River/Creek
- River/Lake

Topography Rating

- 1 - 2
- 2-3
- 3-4
- 4-5
- 5-6
- 6-7
- 7-8
- 8-9
- 9-10



DRASTIC Ranking of Letter T (Topograpghy)

Shoreacres Aquifer

Playmor Junction, British Columbia

Scale: 1:20,000

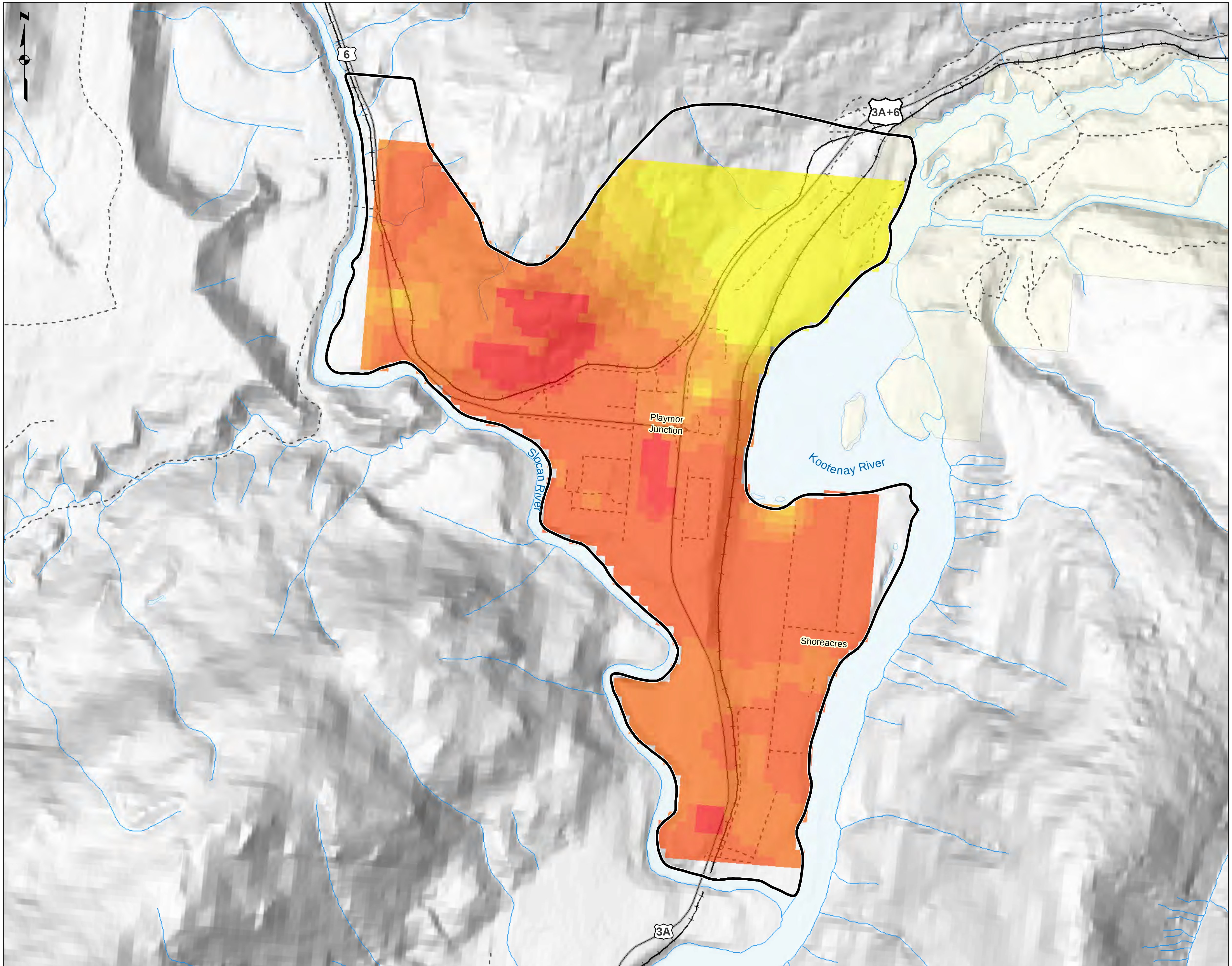
0 0.2 0.4 0.6 0.8 1 Km

Universal Transverse Mercator (Zone 10)

North American Datum (1983)

Report By: AB	WSP Job #: 191-01666-00
Drawn by: AN	Date: May 2, 2019
Reviewed By: AB	Office: Edmonton

Notes:Imagery Source: ESRI IMagery Service

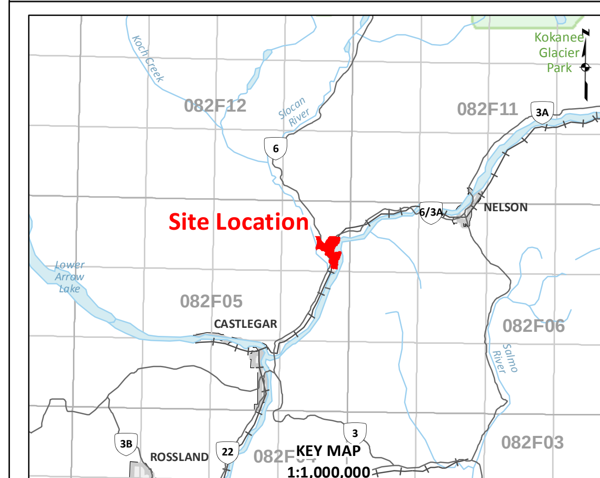


Legend

Study Area
Highway
Paved Road
Train Track
Municipalities
River/Creek
River/Lake

Impact Vadose Zone Rating

1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10



DRASTIC Ranking of Letter I (Imapact Vadose Zone)

Shoreacres Aquifer

Playmor Junction, British Columbia

Scale: 1:20,000

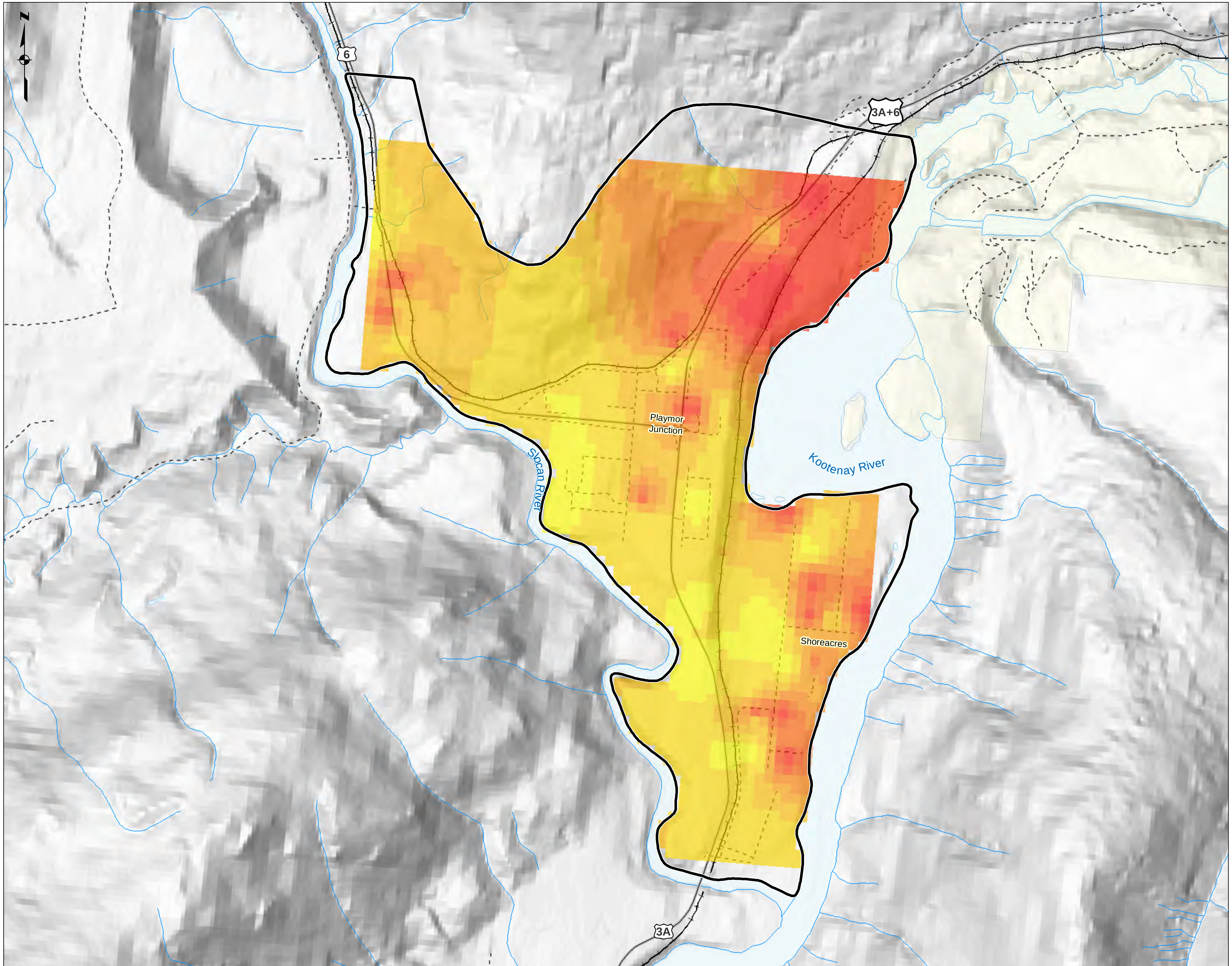
0 0.2 0.4 0.6 0.8 1 Km

Universal Transverse Mercator (Zone 10)
North American Datum (1983)

Report By: AB
Drawn by: AN
Reviewed By: AB

WSP Job #: 191-01666-00
Date: May 2, 2019
Office: Edmonton

Notes:Imagery Source: ESRI IMagery Service

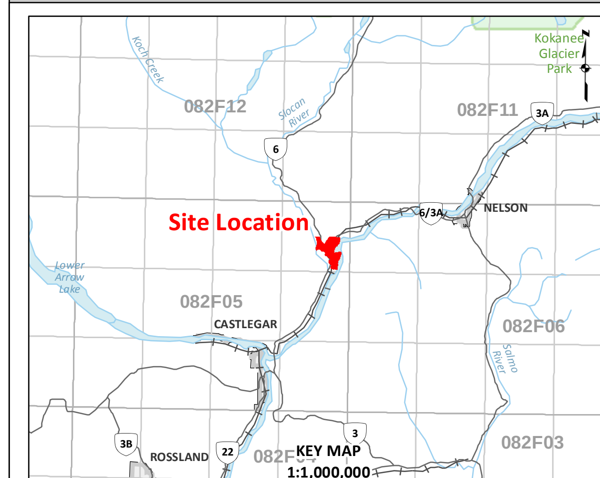


Legend

- Study Area
- Highway
- Paved Road
- Train Track
- Municipalities
- River/Creek
- River/Lake

Conductivity Rating

- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10



DRASTIC Ranking of Letter C (Conductivity)

Shoreacres Aquifer

Playmor Junction, British Columbia

Scale: 1:20,000

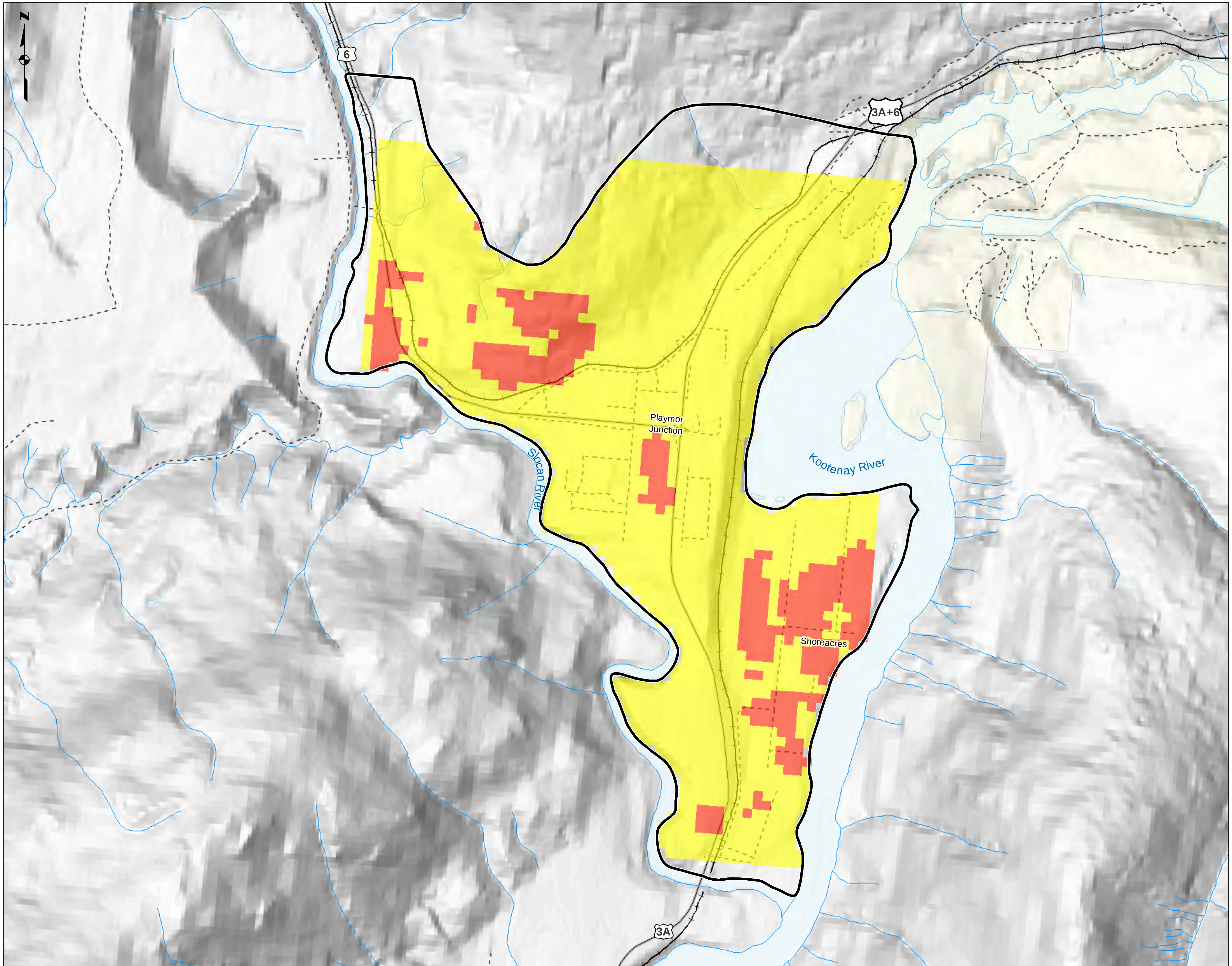
0 0.2 0.4 0.6 0.8 1 Km

Universal Transverse Mercator (Zone 10)
North American Datum (1983)

Report By: AB
Drawn by: AN
Reviewed By: AB

WSP Job #: 191-01666-00
Date: May 2, 2019
Office: Edmonton

Notes:Imagery Source: ESRI IMagery Service

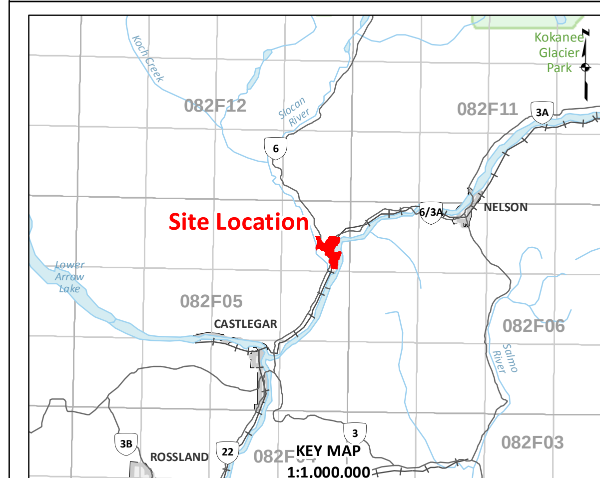


Legend

- Study Area
- Highway
- Paved Road
- Train Track
- Municipalities
- River/Creek
- River/Lake

DRASTIC Vulnerability Index

- 100 - 160
- 160 +



DRASTIC Vulnerability Index

Shoreacres Aquifer

Playmor Junction, British Columbia

Scale: 1:20,000

0 0.2 0.4 0.6 0.8 1 Km

Universal Transverse Mercator (Zone 10)
North American Datum (1983)

Report By: AB	WSP Job #: 191-01666-00
Drawn by: AN	Date: May 2, 2019
Reviewed By: AB	Office: Edmonton

Notes:Imagery Source: ESRI IMagery Service