

### MEMORANDUM

**TO:** Peter Cordingley, Muriel Lake Basin Management Society

**FROM:** Rob Brown and Jocelyn Gray, Matrix Solutions Inc.

- **RE:**Surface Disturbances within Muriel Lake (Alberta) BasinPrepared in accordance with the approved scope of work, dated May 25, 2015
- DATE: November 23, 2015

### **1** INTRODUCTION

Muriel Lake has had consistently declining water levels since the late 1970's. Potential causes and contributing factors of this decline have been examined by a variety of government and private investigations.

On May 25<sup>th</sup>, 2015 Matrix Solutions Inc. provided the Muriel Lake Basin Management Society with a scope of work to complete a desktop assessment to continue assessing, eliminating, and determining the most likely causes of decreasing water levels in Muriel Lake. Some specific data gaps around how linear disturbances such as roads and pipelines developed in the 1970's and 1980's may be affecting the Muriel Lake drainage basin have been identified in previous studies (e.g. Millenium and NHC 2012, Donahue 2006). As part of the scope of work, Matrix proposed a qualitative comparison of subwatershed features using publically available historical aerial photographs and satellite imagery to identify changes in drainage patterns due to surface disturbances around Muriel Lake, with a specific emphasis on known major disturbances. MLBMS approved the surface disturbance portion of the May 25<sup>th</sup> scope of work to be completed in Q3 and Q4 of 2015 and this memorandum describes the results of this assessment.

### 2 METHODS

The methods used to conduct the comparison of subwatershed features using publically available historical aerial photographs to identify changes in drainage patterns due to surface disturbances around Muriel Lake is outlined below.

### **Surface Disturbances**

A time line of known surface disturbances was compiled based off available literature and email correspondence from MLBMS members (Table 1). Major development and surface disturbances around Muriel Lake included:

- Construction of the drainage ditch between Reita Lake and Reita Creek (1960's)
- Construction of the Murphy Oil Road (late 1980's to early 1990's)

• Construction of the high grade road, Highway 657 (1980's)

While this study did not specifically include a literature review, the following data sources were utilized to cross reference the disturbance timeline:

- Historical Interpretation of Water Supply to Muriel Lake in the 20<sup>th</sup> Century (Donahue, 2006)
- Atlas of Alberta Lakes (Mitchell and Prepas, 1990)
- Aerial Examination of Upstream Impediments to Muriel Lake (Maile, 2008)
- Review of Muriel Lake Hydrology (Millenium and NHC, 2012)

Additionally, as part of this work Matrix directed MLBMS to conduct a culvert survey in September 2015 along Hwy 657 and the Murphy Road. MLBMS identified culvert locations, took photographs, indicated culvert heights greater than 10cm above the ground surface, and documented nearby beaver activity.

### **Imagery**

Based on the dates from the surface disturbance timeline, a search for publically available imagery was conducted. Available imagery that was either borrowed from the University of Calgary or found online included:

- 1946 (Government of Canada, 1946)
- 1950 (Government of Alberta, 1950)
- 1959 (Government of Canada, 1959)
- 1972 (Government of Canada, 1972)
- Google Earth Engine (1984-2012)
- Google Earth (2013)

### <u>Comparison</u>

A review of the imagery was completed focussing on changes in drainage associated with surface disturbances identified in the timeline. The coordinates from the culvert survey were used to compare historical air photos from 1959 and 1972 in Google Earth to understand drainage changes associated with specific disturbances in the area.

In addition, the culvert survey observations were used to complete a high level review of the culvert conditions in order to guide MLBMS to make recommendations to the County for planning culvert maintenance activities.

# 3 **RESULTS**

Due to the limited availability of publically available aerial imagery and the varying scales of each photo set, photographic coverage of Muriel Lake within each photo set varied dramatically between years. The years 1959 and 1972 had full coverage of Muriel Lake and the surrounding area. By comparison, 1946 and 1950 showed only partial coverage of Muriel Lake. Surface disturbances and land use changes identified during the review of imagery are summarized below:

### **General/Region**

There were noticeable land use changes between 1946 and 2013, as forested areas transitioned to agricultural land uses or residential uses. The residential areas located on the east and south shores of Muriel Lake developed between 1984 and 2012, and replaced formerly forested and brush (vegetated) land. Highlights observed from the imagery are summarized below.

- 1946 (aerial imagery) There are a few cutlines and clearings present on the north side of Muriel Lake. There is also a road (oriented north-south) and some agricultural land use located on the east shore. The majority of the cover surrounding northeast and northwest Muriel Lake is forest or wetland. There is no photo coverage available for the south shore.
- 1950 (aerial imagery) Agricultural land use is present on the south, west, and east sides of Muriel Lake. Agricultural land use is most prominent on the east side of the lake. The road on the east side of Muriel Lake that is visible in the 1946 photo is also visible in 1950. No other major roads are present in this photo set. There are some cutlines located on the west shore. There is no photo coverage available for the north shore.
- 1959 (aerial imagery) Residence developments are visible on the south shore of Muriel Lake. There are some established cutlines on the west side of Muriel Lake that are more established than in the 1950 photo set. There is also a large low grade road network, oriented east and west, that is present on the north side of Muriel Lake. Expanded agricultural land use is distinguishable on the north end of Muriel Lake, between Muriel and Landry Lakes, and to the north, northeast, and northwest of Landry Lake, than compared to previous years. The south shore of Muriel Lake remains mainly forest, interspersed with wetlands.
- 1972 (aerial imagery) An increase in agricultural land use on the north side of Muriel Lake is visible in the 1972 photo sets. Aerial imagery from previous years shows the north side of Muriel Lake was primarily forested. The low grade road (oriented north-south) on the east side of Muriel Lake is more established than it was in the 1946 and 1959 photo sets. A prominent east-west oriented low grade road is present on the north side of Muriel Lake. This is the same road that was visible in the 1959 photo set. There is no photo coverage available for the south shore.
- 1984-2012 (Google Earth Engine) Residential communities on south and east shores are developing. The Murphy Road and Highway 657 are present. Between 1987 and 1988, the South part of the Murphy Road was constructed.
- 2013 (Google Earth) Residential communities present on south, east, and north shores of Muriel Lake. The Murphy Road and Hwy 657 have been completed on the east and south side of Muriel Lake, respectively.

### Specific Surface Disturbances / Culverts

A high level review of the culvert photos and notes submitted by MLBMS members was summarized in an email to MLBMS on November 3, 2015 and clarified in an email to MLBMS on November 10, 2015 Culvert recommendations were made on the basis of the conditions in Table 2, in order to guide MLBMS in making recommendations to the County for planning culvert maintenance activities. Table 3 summarizes observations about specific culverts after reviewing culvert locations with available aerial imagery. Specific culverts that require further investigation are outlined below with screen captures showing noticeable changes between historical and current images available in Appendix A.

- o Culvert 17: Water body has been split by Hwy 657 between 1959 and 2011 imagery.
- Culvert 15: Open water area is present upstream from this culvert in the 2011 imagery, and is not present in 1972.
- Culverts 14 and 18: Large water body has formed upstream of culvert 14 in the 2011 imagery. Smaller open water area visible in 1972. Culvert 18 is located downstream of culvert 14 and appears to hydraulically connected.
- o Culvert 27: Decreased water levels shown in three water bodies surrounding this culvert between 1959 imagery and 2011 imagery.
- o Culvert 8: Small water body shown in 1972, and is not visible in the 2011 imagery.
- o Culverts 25, 26, 28, and 29: Two small water bodies are visible in 1972 imagery, and decreased water levels are shown in the 2011 imagery.
- o Culvert 6: There is open water visible in the 1972 imagery, but not in the 2010 imagery.
- Culvert 19: A large open water body with a defined downstream drainage is present in the 2015 imagery. In 1959 there was a smaller water body than that shown in 2015 and no defined drainage.

### <u>Reita Lake</u>

The area around the west side of Reita Lake is predominately flat with extensive wetlands and there does not seem to be a continuous, connected drainage toward the Muriel Lake watershed. Ponding can be seen in a wetland on the west side of Reita Lake in the 1972 imagery, which is the result of a well-established beaver dam (as shown in Appendix A). The dam construction indicates flow direction toward Reita Lake, which is consistent with DEM elevation profiles (Google Earth 2013). Although not visible in 1950 and not covered in the extent of the 1959 imagery aerial imagery between 1960 and 1970 may be able to help establish the direction of the drainage prior to the beaver dam. Email correspondence with MLBMS indicates that imagery of Muriel Lake is available for 1962 from the U of A, however it is unknown whether there is coverage for Reita Lake. Additional imagery for Reita Lake may be available for purchase from the Government of Alberta (1967; Table 1). Unless the above imagery suggests a compelling reason to believe drainage at these times was oriented towards Muriel Lake, Matrix suggests that there is not a strong case for the Reita Lake ditch being a major factor in the decline of Muriel Lake water levels. Instead, Matrix suggests that further efforts be channeled to the recommendations in Section 4.

### 4 **RECOMMENDATIONS**

Based on the assessment of aerial imagery, Matrix recommends the following next steps for MLBMS:

- Conduct culvert investigations, as outlined in Table 3 to ensure they are all functioning as intended and to verify some of the observed changes.
- Complete climate analysis looking at long term trends for evapo-transpiration, temperature, and precipitation.
- Develop hydrologic model to determine changes in runoff based on comparison of historical land use (e.g. forested) with current land use (e.g. agriculture, industry, residential) scenarios.

# 5 CLOSURE

We trust that this memorandum will suit your present requirements. If you have any questions or comments, please do not hesitate to call Rob Brown at (403) 727-2136 or Alex Haluszka at (403)513-9435.

Yours truly,

### MATRIX SOLUTIONS INC.

Rob Brown, M.Sc. Senior Water Resources Specialist

### 6 **REFERENCES**

Donahue, W.F. 2006. *Historical Interpretation of Water Supply to Muriel Lake in the 20th Century*. Report prepared for the Lakeland Industry and Community Association. March 2006.

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Millennium EMS Solutions and Northwest Hydraulic Consultants (Millennium). 2012. *Review of Muriel Lake Hydrology*. Report prepared for Pengrowth Energy Corporation. July 2012.

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# Table 1: Timeline of Muriel Lake Events and Summary of Data

Climate Events	1910'5	19205	1930'5	1940'5	1950'5	19605	1970'5	19805	19905	2000'5	Comments:
Avg Annual Precipitation (mm/yr)	378		362	T		459	1		422	1	
Wet Years	1917	1921	1934			1962			1996-97		Increased EEmm over this period
Avg Annual Evapotranspiration (min/y) Air Temp (deg C)						350			302		Increased 1.5 degC over this period
Air Temp & Precipitation - 2012 AENV AGM Presentation		Warmer & d	rier than long	term trend	Co	oler & wetter than lo	ng term trend	Warmer & d	Irier than long ter	m trend	
Legislation & Regulatory Events		•									
Muriel Lake subjected to Regulated Lake Shoreland Development Operation Regulations							1977 - Muriel Lake subjected to regulations; no developmet until management plan development	1980- Lake Management plan developed			Most development prohibited until lake management plan drafted
Moratorium on Muriel Lake water withdrawals								1985			
Surface Disturbance Events						•		•	•		
Drainage Ditch from Reita Lake to Reita Creek						1963-1967					Discussed and modelled to assess sensitivity by Donahue (2006)
Muriel Lake Residence Developments (data from Atlas of Alberta Lakes)						1965 - 16 lots developed	1975- 110 lots developed, 337 lots registered	1988- 186 lots developed, 391 lots registered; Lot distribution- 56% South side of lake, 40% on east side of lake, & 4% located at the northwest end			
Murphy Road Construction								Completed late 8	0's to early 90's		
Hwy 657 Construction (widened and paved)								Completed shortly before Murphy Road, Southern Extension completed in			
Lake Elevation (masl)						1967 559.80 masl Periodic water level monitoring started by Alberta Environment	<b>1974</b> <b>560.43 masl</b> Recent historical maximum	1981 559.90 masl Beginning of high frequency monitoring from Environment Canada		2015 555.36 masl Most recent lake elevation	Lake level decrease = <b>5.07 m</b> from maximum Lake elevation has been below Muriel Creek (outflow) culvert to Landry Lake elevation of 559.66 masl since 1982
Available Imagery											
Gov of Alberta Imagery Search*				1949		1967	1970, 1972	1982, 1986, 1988	1991, 1998	2000	
UofC Aerial Imagery** Google Earth Imagery				<u>1946</u>	1959		1972	1982^ 1984-1989	1990-2000	2000-2013	Google Earth Engine timelapse available for 1984-2012, Current imagery in Google Earth is listed as 2013

### Notes

\* Images are available digitally at a cost of approximately \$18 per township

\*\* Images are free for public viewing and can be borrowed and scanned with membership ^ Records indicate photos are available for this year but library staff were not able to retrieve the information for this work

Imagery reviewed by Matrix for this study

#### Table 2: Muriel Lake Culvert Survey, September 12-15, 2015

		•	Culvert Inlet			Culvert Outlet						
	Coordinates (L	at Long, NAD83)	Photo	Numbers	Is Inlet Invert Above Ground Surface by	If Yes- Measure distance from		Photo N	umbers	Is Outlet Invert Above Ground Surface by more	If Yes- Measure distance from invert to	
Culvert No Zone	Latitude (N)	Longditude (W)	Inlet Toward	Inlet Away	more than 10 cm? (Yes/No)	invert to ground. (cm)	Observations/Comments	Outlet Toward	Outlet Away	than 10 cm?	ground. (cm)	Observations/Comments
												Culvert is raised on South and appears water will flow from the Lake side (North) back to ponded water side (South) (Yes,
12N	54.120	-110.741						#1 yes *See note				more than 10 cm)(15 cm above) Culvert is located on the East side of slough and not at its central (deepest location). Not
1							36" Culvert					placed correctly. Catches only 1/8 of water surface to the high side - There is a dugout located 50 yards to the east side of
												Culvert is almost totally blocked. Not showing on map. Flows toward lake from pasture (North) onto cabin properties. Not a
2 <sup>12N</sup>	54.113	-110.727					12" Culvert not on map	#2 yes *See note				clean run to lake through properties. North side has an existing creek but ground has been altered to restrict flow.
3 12N	54.113	-110.727					24" Culvert not on map	#3 yes *See note				Good drainage bed to and from culvert. Clean, not obstructed. Property owner has a man-made rock drainage path through
401		110 700										Culvert is sloped away from lake. Water has eroded a hole on south side of road from fairly aggressive flow. Culvert may
4 <sup>12N</sup>	54.115	-110.700					24" Culvert not on map	#4 see note	away			need to be re-positioned. Very good flow point for collection but wrong direction.
401	54.407	440.000										Culvert is damaged to the point flow is restricted. Flow is West to East, towards the beaver pond on Muriel Lake Drive.
5 12N	54.107	-110.682					16" Culvert not on map	#5 see note	away west to East			Crosses the East end of Bear Road (45302-TWP-RD-593A) Needs repair. (Yes, more than 10 cm)
401	54.405	440.000										Exiting beaver pond. Culvert is in excellent condition but beavers are beginning to plug off with mud and sticks on south side
6 <sup>12N</sup>	54.105	-110.682					24" Culvert not on map	#6 toward				This culvert is new. Appears to be dammed up on lake side because there is a lot of ponded water.
401	54.007	440.000										Two culverts situated 8ft apart (24" and 14"). One is badly mangled from a plow?? And the 24" is in good condition. Only
7 12N	54.097	-110.668					24" and 14" Culvert Not on map	toward				restriction is when the ditches were brushed the wood pieces are flowing towards inlets and blocking off. (both are 23cm
8 12N	54.101	-110.624					16" Culvert	towards lake				Culvert is in good shape. Not above 10cm. Level with ground. No issue.
401	54.407	110 507										Culvert (32") is in good shape. Questioning the sizing of the culvert. May need to be larger. Large collection area is large. Not
9 12N	54.107	-110.607					32" Culvert not on map	towards				above more than 10 cm. At grade - Good shape.
401		440.505										Culvert (32") is also in good condition. Good access. Not above grade and is flush. Exit is beginning to collect mud and debris
10 <sup>12N</sup>	54.114	-110.606					32" Culvert	towards				blocking @ 50% of the outlet from grade. May need cleaning.
11 12N	54.116	-110.605					32" Culvert	towards				Same as #10
12 12N	54.122	-110.605					7-8' Culvert	towards				Culvert is large (7-8ft). All points are clear. No blockage. Good condition. No issue.
												Culvert is open on the East side, but cannot locate the outlet. Appears that the outlet has had the bank slough on over it or it
13 <sup>12N</sup>	54.141	-110.605					32" Cuvlert					has been removed or blocked on purpose. This one needs "correction".
14 12N	54.155	-110.605	culvert 16 inlet toward	culvert 16 inlet toward	NO		30" Culvert	culvert 16 outlet toward	culvert 16 outlet away	NO		MUD @ OUTLET
15 12N	54.163	-110.605	culvert 17 inlet toward	culvert 17 inlet toward	NO		60" CULVERT-556M APPROXIMATE	culvert 17 outlet toward	culvert 17 outlet away	NO		LARGE BERM (MAN MADE ??) 100M FROM OUTLET
16 12N	54.173	-110.605	culvert 18 inlet toward	culvert 18 inlet toward	NO		24" CULVERT-562M APPROXIMATE	culvert 18 outlet toward	culvert 18 outlet away	NO		
17 12N	54.178	-110.605	culvert 19 inlet toward	culvert 19 inlet toward	CAN'T TELL		30" CULVERT-565M APPROXIMATE-BEAVER DAM COVERING INLET	culvert 19 outlet toward	culvert 19 outlet away	NO		TOP CRIMPED AND MUD FILLED
18 12N	54.156	-110.609	culvert 20 inlet toward	culvert 20 inlet toward	NO		30" CULVERT-571M APPROXIMATE-BEAVER TRAP? @INLET	culvert 20 outlet toward	culvert 20 outlet away	NO		MUD FILLED HARD TO FIND
19 12N	54.120	-110.787	6	6.1	no		Large pond upstream/culvert partially blocked	6.2	6.3	no		Beaver dam downstream
20 12N	54.103	-110.693	5 & 5.1	5.2	no		Tree growth upstream	5.3	5.4	no		Line of trees downstream
21 12N	54.096	-110.673	4	4.1-4.2-4.5No			Large pond upstream/culvert partially blocked	4.3	4.4	No		Culvert 50% filled in
22 12N	54.093	-110.663	13.3	13.2 & 13.4	No		Normal culvert flow	13.1	13	No		Small pond 4x4 meters blocked appears natural
23 12N	54.093	-110.660	14	14.1	No			14.2	14.3	No		Outlet 2/3 filled with earth & sand
24 12N	54.093	-110.651	15	15.1No			Culvert appears normal	15.2	15.3	No		May feed farmers dugout
25 12N	54.093	-110.621	17	17.1	No		Intake partially blocked	17.2-17.3-17.4	17.5	No		Partially blocked-trees growing in outlet
26 12N	54.092	-110.615	18	18.1	No		Culvert completely blocked only 6 cm showing	18.2	18.3	No		
27 12N	54.098	-110.611	11.3	11.1 & 11.2	No		Hwy 657 & Muriel Creek Crossing	11.6 & 11.7	11.4 & 11.5	No		
28 12N	54.091	-110.614	19.2	19 & 19.1				19.4	19.3	No		Outlet 2/3 blocked
29 12N	54.090	-110.614	20.2 & 20.3	20 & 20.1	No		Two culverts	20.5 & 20.7	20.4 & 20.6	Yes	12 cm South Pipe	
30 12N	54.085	-110.614	23.1 & 23.2	23	No		Water flowing - culvert appears normal	23.4	23.3			
31 12N	54.081	-110.615	24.1& 24.2	24-24.3-24.4	60" culvert not functioning in wet area		Series of photos of ponded water & cattails near culvert	24.6	24.5			No water - culvert dry.
No Culvert 12N	54.080	-110.614	25 & 25.1				Ponded area 150 south of 60" dry culvert-appears culvert in wrong location.					
No Culvert 12N	54.104	-110.679					Needs Culvert					Definite water was held back with good slope towards lake. Low point has good funneling from South to North with good slope on North side toward lake. May be a good location for a future culvert.
No Culvert 12N	54.098	-110.659					Needs Culvert	Should flow toward				Low drainage area with good funneling. Have seen water flow over road during spring runoff and with ample rainfalls. Large collection area. Need Consideration.
No Culvert 12N	54.089	-110.615	21				Water in ditch running parrallel to road					
No Culvert 12N	54.087	-110.616	22	21.2			Ponded water					
No Culvert 12N	54.093	-110.625	16	16.1-16.2			Leg. Descr. 12-1-59-W5					Farm appraoch blocking water flow east
No Culvert 12N	54.093	-110.623	12				Should be culvert here					200 meters of cattails - south side

Notes: Jeff and Don completed #1 to 13, Sept. 12, 2015 Richard B completed #14-18, Sept. 14, 2015 Peter C completed #19-31 Sept. 15, 2015

Culvert		Date of Present	Recommendation		
ID	1959	1972	Present	Imagery	
17	<ul> <li>Open water present on upstream and downstream side of road.</li> <li>Evidence of channelization on downstream side of road.</li> </ul>	<ul> <li>Minimal change from 1959.</li> <li>Increased open water visible downstream of road.</li> </ul>	<ul> <li>Open water present on upstream side of road.</li> <li>Reduced open water on downstream side of road.</li> </ul>	August 7, 2011	<ul> <li>Check downstream end of road in spring for open-water.</li> <li>Investigate for debris and capacity.</li> </ul>
16	<ul> <li>Low quality imagery.</li> <li>No open water visible upstream or downstream of road.</li> </ul>	<ul> <li>Low quality imagery.</li> <li>No open water visible upstream or downstream of road.</li> </ul>	<ul> <li>No open water visible upstream or downstream of road.</li> </ul>	August 7, 2011	<ul> <li>No recommendations.</li> </ul>
15	No road visible.	<ul> <li>Evidence of channelization on upstream and downstream side of road.</li> </ul>	<ul> <li>Reduced tree cover along channelized area on upstream side of road.</li> <li>Beaver dam noted.</li> </ul>	August 7, 2011	<ul> <li>Inspect for blocked or perched culvert during spring conditions.</li> <li>Inspect for sediment build up.</li> </ul>
14	<ul> <li>Open water present on upstream end of culvert.</li> <li>Evidence of channelization on upstream and downstream sides of road.</li> </ul>	<ul> <li>Minimal change from 1959.</li> </ul>	<ul> <li>Large increase in open water upstream of road.</li> <li>Large quantity of open water on upstream side of road</li> </ul>	August 7, 2011	<ul> <li>Verify culvert location relative to upstream open water body.</li> <li>Inspect for blocked or perched culvert condition.</li> <li>Note extent of open water on upstream side of road in spring.</li> <li>Note any</li> </ul>

# Table 3: Summary and Recommendations for Culverts Surrounding Muriel Lake

Culvert		Date of Present	Recommendation		
ID	1959	1972	Present	Imagery	
					possible beaver activity.
18	• No road visible.	<ul> <li>Minimal change from 1959.</li> </ul>	<ul> <li>Culvert is located on a channelized area, downstream of culvert 14.</li> </ul>	August 7, 2011	<ul> <li>Inspect for blocked or perched culvert condition.</li> <li>Note any possible beaver activity.</li> </ul>
13	<ul> <li>No road visible.</li> <li>Low quality imagery.</li> <li>No open water visible upstream or downstream of road.</li> </ul>	<ul> <li>Minimal change from 1959.</li> </ul>	Minimal change from 1959.	August 7, 2011	<ul> <li>No recommendations.</li> </ul>
12	<ul> <li>No road visible.</li> <li>Evidence of open water in upstream area.</li> </ul>	<ul> <li>Minimal change from 1959.</li> </ul>	<ul> <li>Slightly reduced open water on upstream side of road.</li> </ul>	August 7, 2011	<ul> <li>No recommendations.</li> </ul>
11	<ul> <li>Low quality imagery.</li> <li>No open water visible upstream or downstream of road.</li> </ul>	<ul> <li>Minimal change from 1959</li> </ul>	• Minimal change from 1959.	August 7, 2011	<ul> <li>No recommendations.</li> </ul>
10	No road visible.	<ul> <li>Increased channelization visible downstream of road.</li> </ul>	<ul> <li>Increased channelization visible downstream of road.</li> </ul>	August 7, 2011	<ul> <li>No recommendations.</li> </ul>
9	<ul> <li>No road visible.</li> </ul>	<ul> <li>No road visible.</li> <li>Increased agricultural activity in upstream area.</li> </ul>	<ul> <li>No open water visible on upstream or downstream side of road.</li> </ul>	August 7, 2011	<ul> <li>No recommendations.</li> </ul>
27	No road visible.	Minimal change from	Reduced open water on	August 7, 2011	Inspect for

Culvert		Date of Present	Recommendation		
ID	1959	1972	Present	Imagery	
	<ul> <li>Evidence of channelization in upstream and downstream areas.</li> </ul>	1959.	<ul> <li>downstream end of road, wetland remains.</li> <li>May be increase in open water on upstream side of road.</li> </ul>		blocked or perched culvert condition.
8	<ul> <li>No road visible.</li> </ul>	<ul> <li>Minimal change from 1959.</li> </ul>	<ul> <li>Reduced open water west on downstream end of road.</li> </ul>	August 7, 2011	<ul> <li>Inspect for blocked or perched culvert condition.</li> </ul>
25	<ul> <li>No road visible.</li> <li>Evidence of channelization in upstream and downstream areas.</li> </ul>	<ul> <li>No road visible.</li> <li>Minimal change from 1959.</li> </ul>	<ul> <li>Reduced open water on upstream side of road.</li> <li>Inlet of culvert is deformed; 6cm of space between top of culvert and sediment deposit.</li> </ul>	August 7, 2011	<ul> <li>Inspect for blocked or perched culvert condition.</li> <li>Check downstream end of road in spring for open-water.</li> </ul>
26	No road visible.	<ul> <li>No road visible.</li> <li>Minimal change from 1959.</li> </ul>	<ul> <li>Reduced open water on downstream side of road.</li> </ul>	August 7, 2011	<ul> <li>Inspect for blocked or perched culvert condition.</li> <li>Check downstream end of road in spring for open-water.</li> </ul>
28	No road visible.	<ul> <li>No road visible.</li> <li>Minimal change from 1959.</li> </ul>	<ul> <li>Reduced open water on downstream side of road.</li> </ul>	August 7, 2011	<ul> <li>Inspect for blocked or perched culvert condition.</li> <li>Check downstream end of road in spring for open-water.</li> </ul>
29	No road visible.	No road visible.	Reduced open water on	August 7, 2011	Inspect for

Culvert		Date of Present	Recommendation		
ID	1959	1972	Present	Imagery	
		<ul> <li>Minimal change from 1959.</li> </ul>	downstream side of road.		<ul> <li>blocked or perched culvert condition.</li> <li>Check downstream end of road in spring for open-water.</li> </ul>
30	No road visible.	<ul> <li>No road visible.</li> <li>Minimal change from 1959.</li> </ul>	<ul> <li>Increased land clearing on upstream area of road.</li> </ul>	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
31	No road visible.	<ul><li>No road visible.</li><li>Minimal change from 1959.</li></ul>	<ul> <li>Increased land clearing on downstream area of road.</li> </ul>	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
22	No road visible.	<ul><li>No road visible.</li><li>Minimal change from 1959.</li></ul>	Minimal change from 1959.	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
23	No road visible.	<ul><li>No road visible.</li><li>Minimal change from 1959.</li></ul>	<ul><li>Minimal change from 1959.</li><li>Water flowing in photos.</li></ul>	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
24	No road visible.	<ul> <li>No road visible.</li> <li>Minimal change from 1959.</li> </ul>	Minimal change from 1959.	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
7	No road visible.	<ul> <li>Minimal change from 1959.</li> </ul>	<ul> <li>Increased land clearing on upstream area of road.</li> </ul>	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
21	No road visible.	<ul><li>No road visible.</li><li>Minimal change from 1959.</li></ul>	<ul> <li>Increased land clearing on upstream area of road.</li> </ul>	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
6	<ul> <li>No road visible.</li> <li>Evidence of channelization in upstream and</li> </ul>	<ul> <li>Minimal change from 1959.</li> <li>Increased land clearing on upstream areas of</li> </ul>	<ul> <li>Increased land clearing on upstream areas of road.</li> <li>Open water visible on upstream end of road.</li> </ul>	May 12, 2010	<ul> <li>Inspect for blocked or perched culvert condition.</li> </ul>

Culvert		•	Date of Present	Recommendation	
ID	1959	1972	Present	Imagery	
	downstream areas.	road.	<ul> <li>Evidence of reduced channelization downstream of road.</li> </ul>		
5	No road visible.	<ul> <li>Minimal change from 1959.</li> <li>Increased land clearing on upstream areas of road.</li> </ul>	<ul> <li>Increased land clearing on upstream areas of road.</li> </ul>	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
20	<ul> <li>No road visible.</li> <li>Evidence of channelization in upstream and downstream areas.</li> </ul>	<ul> <li>Increased channelization in upstream area.</li> </ul>	<ul> <li>Increased land clearing on upstream and downstream areas of road.</li> </ul>	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
4	No road visible.	<ul> <li>Evidence of increased channelization downstream.</li> </ul>	<ul> <li>Increased land clearing upstream and increased development downstream.</li> </ul>	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
2	No road visible.	<ul> <li>Minimal change from 1959.</li> <li>Increased development downstream of road.</li> </ul>	<ul> <li>Increased land clearing on upstream area of road.</li> </ul>	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
1	<ul><li>No road visible.</li><li>This area was at the lake front.</li></ul>	<ul> <li>Minimal change from 1959.</li> </ul>	<ul> <li>Increased land clearing and development on upstream area of road.</li> </ul>	May 12, 2010	<ul> <li>No recommendations.</li> </ul>
19	<ul> <li>No road visible.</li> <li>Evidence of channelization in downstream area.</li> </ul>	<ul> <li>No imagery available.</li> </ul>	<ul> <li>Beaver activity noted.</li> <li>Evidence of increased channelization and open- water in upstream area.</li> </ul>	May 12, 2010	• Inspect for blocked or perched culvert condition.

# APPENDIX A

Aerial Imagery Comparisons for Muriel Lake Culverts and Reita Lake Drainage

2011:





2011:





# Culvert 14 and 18

2011:





2011:





2011:





<u>Culverts 25, 26, 28, 29</u>

2011:





# <u>Culvert 6</u>

2010:





2015:





# <u>Reita Lake</u>



