APPENDIX ‘B’

HYDRAULIC REPORT

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File #969-30

Mr. Michael Tsen, P.Eng.
Bridge Engineer
Stantec Consulting Ltd.
905 Waverley Street
Winnipeg, Manitoba
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Dear Sir:

Re: City of Winnipeg, Gunn Road and Day Street Intersection Realignment
Cordite Ditch Crossing Replacement

As requested, UNIES Ltd. has reviewed the hydrologic and hydraulic regime relevant to the above-referenced road crossing site, and herein we provide our conclusions and recommendations concerning a proposed replacement for the existing two corrugated metal pipe culverts. The analysis consisted of:

(a) site observations completed on October 28 and October 30, 2009,

(b) reviews and office studies to estimate the hydrologic and hydraulic behaviour which would be expected affect the crossing site during the life of a replacement crossing system, and

(c) the determination of key minimum design dimensions to ensure acceptable hydraulic performance.

1.0 Background

In brief, the existing Cordite Ditch, a linear constructed drain, runs in a southeast-to-northwest direction north of the built-up residential portion of Transcona. The linear alignment of the drain meets and crosses both the north-south Day Street and the east-west Gunn Road very close to the point where the two grid roads would naturally have intersected at right angles.

The construction of the Cordite Ditch, at one time an important channel that carried drainage waters toward Bunn's Creek from the area of the old Defense Industries Limited's cordite manufacturing plant, an approximately 400-hectare site located east of Transcona, pre-dated much of the area's development that is visible today. Old National Topographic Series (NTS) topographic maps from the immediate post WWII era, based on land surveying and aerial photography compiled in the interval 1937 to 1948, show an abandoned rail line along the

route of the present drain, and no drain. When the drain now known as the Cordite Ditch was excavated to its present dimensions is unclear. The cordite plant was most active between 1941 and 1945 and was demolished after the war.

The upstream end of the watershed feeding the Cordite Ditch was cut off by the construction of the Winnipeg Floodway in the 1960s, and now discharges separately into the Floodway. Subsequent new urban residential development at the east end of Transcona between Day Street and the Winnipeg Floodway and south of the Manitoba Hydro transmission right of way, and the installation of the Perimeter Highway (PTH 101), with further development of the City of Winnipeg's separate sewer network, recreational wetlands sites and dug drains have combined to result in a significant additional reduction in the area actively draining surface runoff to the old Cordite Ditch. Presently, a land area of about 3.5 square kilometres east of Day Street is drained by a combination of the Cordite Ditch and a tributary roadside drain along the south side of Gunn Road. **Figure 1** shows the location and extent of the Gunn Road / Day Street drainage area.

Surface soils within the drainage basin are primarily Osborne and Red River Clays which are poor to imperfectly drained soils developed on moderate to strongly calcareous fine lacustrine clay deposits. Permeability and surface runoff are slow to very slow and there are several very shallow depressions in which water tends to pond. The general land gradient of slightly less than 0.001 is toward the west but localized undulations in the near-flat land surface produce a range of normal directions of surface flow in some subbasins.

South of Gunn Road and within the drainage basin the land remains mostly undeveloped despite the proximity to significant urbanization. There are a handful of residential properties and a few light industrial operations along the south side of Gunn Road and the east side of Day Street which have decreased local permeability while embankments and dug drains along the Cordite Ditch and various rail lines serve to interrupt natural surface runoff paths. A transmission line corridor runs along the south side of the basin. There is a small contribution to basin runoff from the line of residential properties, school and playgrounds situated immediately adjacent to the south side of the transmission right of way. The open land stands idle or is cropped during the open water season and is viewed and utilized as having significant recreational and natural value within the urban environment. The ultimate path and pace of future land-use changes and further urban development for this part of the drainage basin may be considered undefined at the point in time of this analysis.

North of Gunn Road, on either side of Redonda Street and south of the Canadian Pacific railway line, there has been the recent introduction of municipal infrastructure and development of commercial and light industrial properties, which is significantly increasing the proportion of near-impervious to pervious land surface in the area The placement of roads has been accompanied by the creation of associated wide and shallow drainage channels along the frontage and, in some cases, behind the new businesses. To manage the consequential increased runoff response from the new areas of development and ease peak discharges along the south ditch of Gunn Road, temporary runoff storage capacity has been incorporated on the north side of Gunn Road east of the rail crossing in a naturally low area. Within the quarter section of land immediately northeast of the intersection of Gunn Road and Day Street, only the properties lying close to Gunn Road are considered to discharge local runoff toward that corner,

with the rest of it assumed to be captured and held indefinitely by the natural ponds or manmade dugouts that can be seen there in **Figure 1**.

When they were eventually completed, the west and east sections of the grid-road-aligned Gunn Road at Day Street were offset at Day Street, possibly to simplify the vehicular crossing of the existing railway at that time. Today, the offset intersection remains in service and the Cordite Ditch passes under Day Street via two corrugated steel pipe (CSP) culverts about 16 metres in length. **Figure 2** shows downstream and upstream views along the Cordite Ditch, observed from the existing hydraulic structure at Day Street. **Figure 3** shows views of typical land use and dug drainage features within the Cordite Ditch contributing drainage basin.

In this report, a proposal to realign the Day Street and Gunn Road junction to a right-angled single intersection with the Cordite Ditch passing under the crossing via an 80-metre long, reinforced concrete box culvert, is examined from a hydrologic and hydraulic perspective in order to estimate the required minimum dimensions of the new structure.

2.0 Hydrologic and Hydraulic Analysis

2.1 Data Sources

The following information was utilized in the estimation of the hydrologic and hydraulic design conditions applicable to the Cordite Drain crossing site at the intersection of Gunn Road and Day Street:

(a) Natural Resources Canada NTS topographic maps.

(b) Web-based aerial imagery, e.g., Google Inc., 2009.

(c) Inspection of Gunn Road and Day Street area topography, land use, urban development, industrial/commercial development, natural drainage, dug drainage and existing drainage conduits, from proposed crossing site to upstream perimeter of contributing drainage area, October 28 and October 30, 2009.

(d) Stantec Consulting Ltd. detailed local topographic survey in the vicinity of the Day Street and Gunn Road intersection, including typical cross sections of the drainage channels and earth embankments in the immediate proximity (summarized in Stantec Sketch # 5170/1, /2, /3, /4).

(e) Stantec Consulting Ltd. Draft Box Culvert Plan, Elevations, and Sections, 05170S-101-xxx, December 2009.

(f) Manitoba Water Stewardship estimated flood frequency determination method for small rural watersheds using the Rational Method.

(g) US Army Corps of Engineers hydrologic modelling system, HEC-HMS 3.4.

(h) US Army Corps of Engineers one-dimensional backwater simulator, HEC-RAS 4.0.

(i) Kent, K.M., A Method of Estimating Volume and Rate of Runoff in Small Watersheds, U.S. Department of Agriculture, Soil Conservation Service, SCS TP-149, 1973.

(j) City of Winnipeg Water and Waste Department, Report on Extreme Rain Event - July 17, 2005, July 2005.

(k) Manitoba Department of Municipal Affairs, Municipal Planning Branch, Soils of the Winnipeg Region Study Area, Canada - Manitoba Soil Survey, , 1975.

(l) U.S. Department of Transportation, Federal Highway Administration, Hydraulic Design of Energy Dissipators for Culverts and Channels, Chapter 10: Riprap Basins And Aprons, Hydraulic Engineering Circular Number 14, Third Edition, July 2006.

(m) Chow, Ven Te, Open-Channel Hydraulics, McGraw-Hill, New York, 1959.

(n) Fisheries and Oceans Canada, Draft Fish Habitat Classification Maps for Manitoba Agricultural Watersheds, 2007.

2.2 Site Hydrology: Estimation of Design Discharges

For very small drainage areas and corresponding drainage channels such as the Gunn Road / Cordite Drain area east of Day Street that is considered here, the design runoff event that is hydraulically important to culverts and bridges is invariably the intense rainstorm event. In southern Manitoba, the 6- or 12-hour rain storm is typically applied. Estimation of runoff response to a precipitation input, or a simulation of the physical phenomenon, is complicated by the fact that the usual small watershed is rarely one whose runoff has ever been observed quantitatively, so there is no way to calibrate, or tune, the artificial representation, or model, of the phenomenon. Most often, and due to the relative unimportance of the small amounts of rainfall runoff and the value of the structures and facilities being designed to accommodate it, rules of thumb are employed, and they are usually quite sufficient.

To provide greater comfort in the selection of structure dimensions for the proposed box culvert at the intersection of Gunn Road and Day Street, it may be considered reasonable to examine further the sensitivity of estimated runoff rates to the assumptions used in their determination. This approach is taken below. A simple physical representation of the basin runoff process is prepared and realistic frequency-based Winnipeg rainfall events are applied to it in order to generate runoff hydrographs in the Cordite Ditch at the site of the proposed culvert. Regardless of the suggested rigour of this exercise, the drainage basin is still ungauged, and the model cannot be verified quantitatively. Design discharges are selected from these results on the basis of the sensitivity trials, experience with similar settings, and a detailed field inspection concluded in October of 2009 under no-flow conditions.

2.2.1 Precipitation-Runoff Model

Intensity-Duration-Frequency (IDF) curves representing Winnipeg area conditions are compared in **Table 1**. The widely used AES summaries have not been updated recently, and

show slightly lower intensities than the data attributed to the City of Winnipeg's Water and Waste Department, which may have been derived from newer Winnipeg weather data. It has been generally observed that severity of extreme weather and related runoff has increased in recent years, possibly a reflection of actual climate change impacts, or maybe indicative of other forces. Therefore, for purposes of rainfall-runoff estimation applicable here to the Gunn Road / Day Street intersection, rainfall intensities derived from the highest set of values from **Table 1** have conservatively been adopted. Focus in the analysis was on storms with expected return periods of 25, 50, and 100 years, in other words, the 4%, 2%, and 1% annual exceedance events.

Table 1.

Precipitation Totals for Storms of Different Durations, Winnipeg

Annual Exceed. Freq	Return Period years	Env Canada, AES Winnipeg Int'l. A. [1944-1990] Total mm in period			Env Canada, AES Wpg. composite Hangarline Road [1944-1996] Total mm in period			City of Winnipeg Water and Waste (2005) Total mm in period		
		15 min	6 hr	12 hr	15 min	6 hr	12 hr	15 min	6 hr	12 hr
1%	100	35.4	84.8	94.0	34.7	88.6	96.5	40.4	89.0	99.2
2%	50	32.2	77.0	85.5	31.5	80.4	87.7	35.8	80.1	89.9
4%	25	28.9	69.2	77.0	28.4	72.1	78.9	31.8	71.0	79.2
10%	10	24.4	58.7	65.4	24.1	61.0	67.0	26.3	59.2	66.4
20%	5	20.9	50.3	56.3	20.7	52.1	57.6	22.3	51.0	57.7
50%	2	15.6	37.7	42.5	15.6	38.8	43.4	16.6	38.8	43.8

Rainfall events were assumed to fall evenly over the entire Cordite Ditch watershed tributary to the proposed Gunn Road and Day Street intersection box culvert. The small watershed of about 3.5 square kilometres was subdivided for purposes of analysis into 11 subbasins in order to reflect, in a reasonable way, the following:

(a) the uneven distribution of land uses throughout,

(b) variations in the influence of impervious surfaces in different parts of the contributing watershed,

(c) local overland flow directions and approximate surface gradients,

(d) distances from point of initial ground contact to point of concentrated flow, then to linear drain, then to main drain.

The adopted model layout is shown in **Figure 4**, including conceptual sub-basins, assumed runoff directions, excess runoff storage area, and the main drains leading to the Cordite Ditch crossing of the Gunn Road and Day Street intersection.

The most intense part of each design storm was assumed to occur at its midpoint. For conversion of the rain into runoff, the familiar and consistent SCS Curve Number (CN) method of the U.S. National Resources Conservation Service (formerly Soil Conservation Service [SCS]) has been applied first, to determine the quantity of water that would run off along the land surface. Based upon the tight clay soils with scattered, very shallow depressions (i.e., similar to SCS Hydrologic Soil Group D [soils that swell significantly when wet, heavy plastic clays and certain saline soils]), which are mostly covered by crop, crop residue, grasses, and grazing land in good hydrologic condition, a Curve Number of 80 has been adopted for this analysis. Sub-basin imperviousness was established between 0 and 30% of total area, dependent upon the assumed land use and level of development. Pre-storm runoff rates were assumed to be negligible, reflective of the ephemeral nature of the drains in the basin.

For transmission of surface runoff to basin outlets, the Kinematic Wave conceptual watershed model has been applied to each sub-basin with representative flow path lengths to the sub-basin outlet. Lateral ground slopes were assumed to be 0.0002, with internal drain and ditch bottoms at 0.0005, both generally similar to the actual land gradients observed in the basin. An overland roughness coefficient of 0.2 was adopted, a value typical of short to long grasses. The channel roughness (Manning's n) of grassy drains and ditches was set to 0.045. Main drains were assumed to be at slope of 0.0007, similar to that of the terrain followed by the Cordite Ditch upstream and downstream of the Gunn Road and Day Street intersection. Manning's n was held at 0.045.

With the above assumptions about runoff characteristics, much of the attenuation of rainstorm runoff occurs with the slow release of excess runoff from the sub-basins to the internal and bordering drains. The drains tend to provide a slight delay in transmission of the peak runoff to downstream points without much impact on the peak rates from the upstream to downstream end of a section of channel. The smoothing and staggering of the arrival of peak flows from different sub-basins at the downstream point of interest, in this case the site where the new box culvert would be installed, serves to blunt the sharpness of the peak and spread it out over a bit longer time.

Typical rainfall-runoff model results for the Gunn Road and Day Street intersection, with flows moving downstream from that point in the Cordite Ditch, are shown in **Figure 5**. For this watershed, the highest runoff rates from the design storms are estimated to last a few hours, with the bulk of the runoff discharged within two days, assuming no downstream congestion. A summary of the overall results is shown in **Table 2**.

Table 2.

Estimated Peak Runoff Rates in CMS for Selected Storms
Cordite Ditch at Gunn Road and Day Street

Annual Exceedance Event	12 hour storm	6 hour storm
1% (average return period of 100 years)	5.5	4.9
2% (50 years)	4.6	4.0
4% (25 years)	3.6	3.2
50% (2 years)	0.8	0.6

2.2.2 Selection of Discharges for Hydraulic Design Studies

The peak flowrate estimates shown in **Table 2** may be understood to be subject to wide confidence bands (i.e., a lack of) because of the ungauged nature of the subject watershed, together with a prevailing general uncertainty about further urban development during the working life of proposed box culvert in the Cordite Ditch at Day Street and Gunn Road. The future could include the prospect of possible conversion of some of the agricultural lands of the basin into uses which would tend to reduce the ability of the soil to absorb, store, and attenuate surface runoff from intense rainfall events. It is also possible that further expansion of nearby residential, commercial, or industrial development into the area could be accompanied by extension of urban stormwater management infrastructure which could tend to divert and reduce peak discharge rates in the Cordite Ditch.

Respectful of the future uncertainty outlined above, rates of discharge up to the estimated peak magnitudes shown in **Table 2**, and a little higher, are used in an assessment of the expected hydraulics and the required dimensions for a reinforced concrete box culvert at the site.

2.3 Site Hydraulics

A one-dimensional hydraulic model of the Cordite Ditch at the Gunn Road and Day Street intersection was used to estimate hydraulic performance of reinforced concrete box culverts of varying sizes in order to arrive at suitable minimum design dimensions.

Layout of the tested conduits was prepared on the basis of Stantec Consulting Limited detailed site survey, which included channel cross sections and ground and existing roadway elevations upstream, downstream, and at the intersection. Basic minimum dimensions and form of a box culvert for the site were assumed from discussion with Stantec design personnel and City of Winnipeg Water and Waste Department staff.

Face-to-face length along the axis of the proposed single-cell (barrel) conduit was taken as 71.235 metres. The downstream headwall is typical for a straight channel such as the Cordite Ditch, and is aligned perpendicular to the barrel axis with wingwalls flared 70 degrees off the stream and culvert axis. The upstream headwall is skewed 67 degrees from perpendicular, reflecting proximity of the east west alignment of Gunn Road and the shallow angle between it and the Cordite Ditch (23 degrees).

Hydraulic performance of the skewed inlet is estimated to be insignificantly changed from that of a right-angled entrance for the range of flow rates and entrance velocities anticipated. The approaching channel and flow direction would be parallel, and in line with, the culvert axis centreline. A tendency for debris buildup and encroachment on the left, or south, side of the entrance may be a possible feature of the skewed inlet, although the field inspection of the contributing watershed done as part of this study suggests that there should not normally be much natural floating debris production and downstream movement.

Theoretical normal flow depths for several discharges in the Cordite Ditch at the Gunn Road and Day Street intersection are shown in **Table 3**, under the assumptions of a downstream average channel gradient of 0.0007, cross sections as surveyed, and a Manning's roughness coefficient, n, of 0.035, assuming a clean channel and no downstream constrictions or congestion. Most of the time, there is almost no flow in the ditch, but it carries spring melt waters and the results of significant rainfalls. Expected flow depths are generally low due to the oversized cross section of this formerly more important drain. Localized unevenness in the bottom profile of the Cordite Ditch and other drains in the area have resulted in reaches of standing water whose depths vary over time dependent on long-term soil moisture and groundwater conditions. Some of the culverts within the basin are perched and/or damaged, and may pond water, at least temporarily, against their upstream sides.

Table 3.

Estimated Normal Water Surface Elevations (CGVD) of Peak Flows for Selected Storms Cordite Ditch at Gunn Road and Day Street

Annual Exceedance Event	12 hour storm	6 hour storm
1% (average return period of 100 years)	232.3	232.2
2% (50 years)	232.2	232.1
4% (25 years)	232.1	232.1
50% (2 years)	231.7	231.7
Ground (thalweg / DS culvert invert)	231.3	231.3

The vertical dimension (rise) of the proposed box culvert has been assumed to be 1.8 metres, a minimum dimension required by the City of Winnipeg Water and Waste Department for inspection and maintenance access. Estimated hydraulic performance of a range of possible spans (horizontal dimension) is summarized in **Figure 6**. All results shown in the figure reflect continuously maintained atmospheric conditions along the full length of the culvert barrel and relatively relaxed inlet and outlet conditions. For higher flows and narrow spans, the conduit could theoretically fill, inlet and outlet transitions develop disproportionate energy losses, and the structure may be overtopped.

2.3.1 Recommended Hydraulic Design for Reinforced Concrete Box Culvert

It is recommended on the basis of the examination of the contributing watershed hydrology and the hydraulic modelling trials described above that the minimum span of the culvert barrel be set at 2.5 metres. The following factors were considered most significant to this determination (in no particular order):

(a) ungauged basin, including uncertainty in estimated impedance and infiltration characteristics;

(b) uncertain future land development and runoff attenuation characteristics over a significant part of the total 3.5 square kilometre contributing watershed;

(c) with moderate projection of extent of impervious areas, the estimated 100-year / 12-hour storm peak runoff for Cordite Ditch culvert site at Day Street and Gunn Road intersection is 5.5 cubic metres per second (CMS). The corresponding 50-year / 12-hour storm peak runoff is estimated at 4.6 CMS, and the 25-year, 12-hour storm peak runoff is estimated at 3.6 CMS;

(d) from **Figure 6**, the total head loss at the 1.8 X 2.5 m structure is estimated to reach 0.58 metres for a discharge of 5.5 CMS, 0.49 for a discharge of 4.6 CMS, and 0.40 for a discharge of 3.6 CMS;

(e) at 5.5 CMS, the average velocity across the flow section in the backed up deeper water upstream of the culvert is estimated to be 0.25 metres per second (m/s), increasing to an average of 2.45 m/s in the barrel, and dropping back to an average of 0.55 m/s downstream of the culvert. Corresponding average barrel velocities for 4.6 and 3.6 CMS are estimated to be 2.23 and 2.00 m/s, respectively;

(f) at 5.5 CMS, the estimated total energy loss of 0.57 metres at the structure is estimated to be divided into: entrance loss of 0.18 m, friction loss in the barrel of 0.12 m, and expansion loss at the exit of 0.27 m. An approximate hydraulic profile for this discharge is shown in **Figure 7**;

(g) discharges up to approximately 9.5 CMS are estimated to remain at atmospheric pressure in the barrel, without surcharging and risk of overtopping the roadway;

(h) high velocity periods are limited to a few hours per episode, with passage of the full storm runoff hydrograph within two days; and

(i) the Cordite Ditch upstream (east) of Plessis Road is considered as Habitat Type E, or indirect habitat (simple habitat in ephemeral stream, providing water and nutrients downstream), according to draft Fish Habitat Classification system for Manitoba Agricultural Watersheds.

From the above, in summary, the recommended gross dimensions for a reinforced concrete box culvert for the Cordite Ditch at the Gunn Road and Day Street intersection are: rise X span = 1.8 X 2.5 metres. It is assumed that all four inside corners of the single rectangular barrel would have fillets of dimension 0.3 X 0.3 m. Centreline box length would be 71.235 metres, and, with the skewed entrance described above, total footprint of the structure including wing walls would be almost 80 metres.

The invert of the rectangular opening should be set at the elevation of the existing bottom of the Cordite Ditch upstream and downstream and in conformance with the normal channel slope at the site (approximately 231.3 m at the downstream end, 231.45 m at the upstream end) in order to minimize both upstream ponding and sediment accumulation within the culvert barrel.

Protection against scour and change of elevation of the dug channel bottom located immediately upstream and downstream of the reinforced concrete cut-off walls should be provided. Transitions to entrance and exit velocities of about 2.5 metres per second from the more languid flows approaching and drawing away from the conduit under design conditions should be accommodated, as the transitions would be occurring mostly beyond the limits of the reinforced concrete structure. The proposed cut-off wall depth below the culvert invert is 0.9 metres, which should be more than adequate for the moderate entrance and exit velocities expected.

From application of the U.S.DOT FHWA procedure to estimate rock riprap apron dimensions, a D_{50} stone size of about 175 mm would be recommended, with minimum average dumped rock thickness of $2D_{50}$, or 0.35 m, from the culvert exit invert as far out as 8.5 metres with flaring to match the channel bottom. At the culvert entrance, it may be desirable to provide additional rip rap on the left or south side of the channel as a minor guide to reorient approaching flows tending to be reflected off and along the right side wing wall toward the culvert entrance. The layout of riprap layers at both ends may be most suitably finalized by visual inspection once the constructed setting of realigned roadways and the disturbed Cordite Ditch becomes apparent.

The above summarizes our assessment of the hydrology and hydraulics relevant to the Cordite Ditch reinforced concrete box culvert at Day Street and Gunn Road in conjunction with the realignment and simplification of the the intersection. Please contact the undersigned as required.

Yours truly,

Campbell D. MacInnes, Ph.D., P.Eng.
UNIES Ltd.

Figure 1. Location Plan, Proposed Box Culvert Installation along Cordite Ditch - City of Winnipeg Gunn Road and Day Street Intersection Realignment.

(a)

(b)

Figure 2. Cordite Ditch at Day Street: (a) constructed channel, upstream view, (b) constructed channel, downstream view.

(a)

(b)

Figure 3. Cordite Ditch above Day Street: (a) example of remnant historical tributary drain, the largest remaining (b) typical example of modern tributary drain constructed alongside main thoroughfare (Day Street).

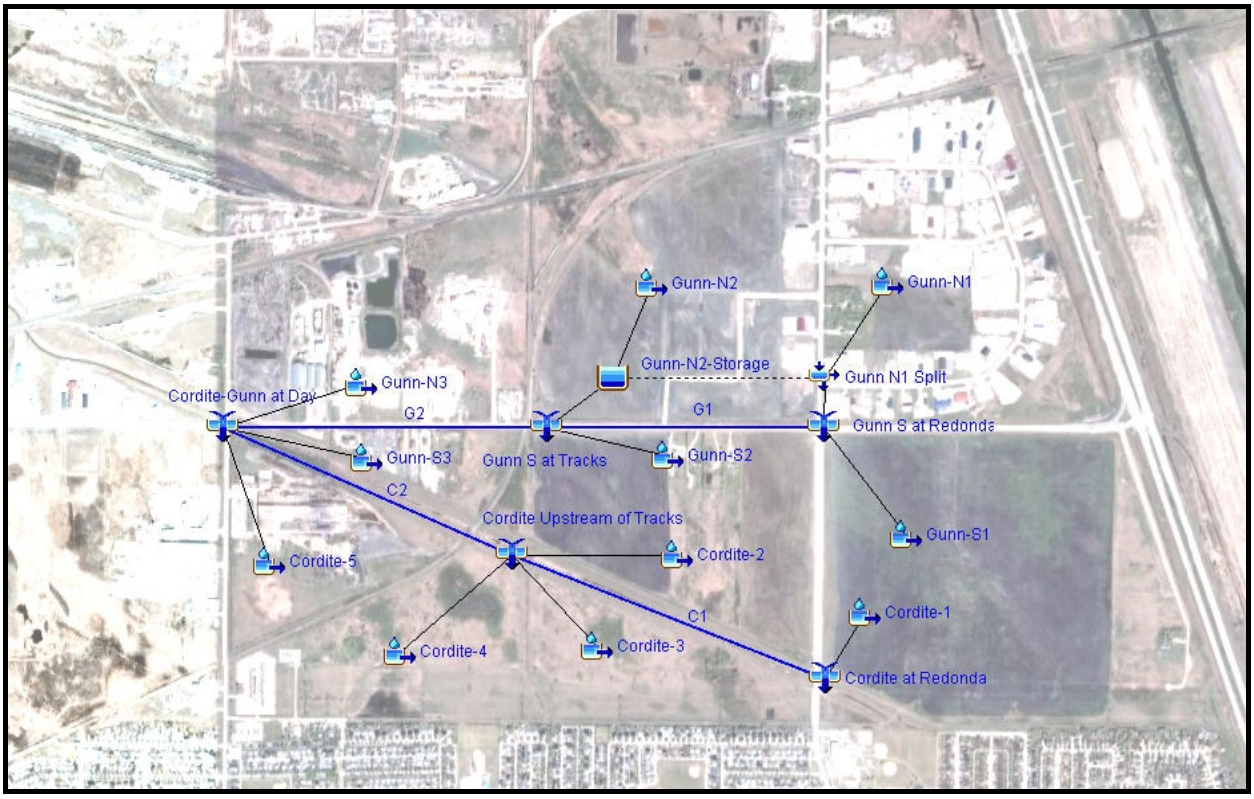
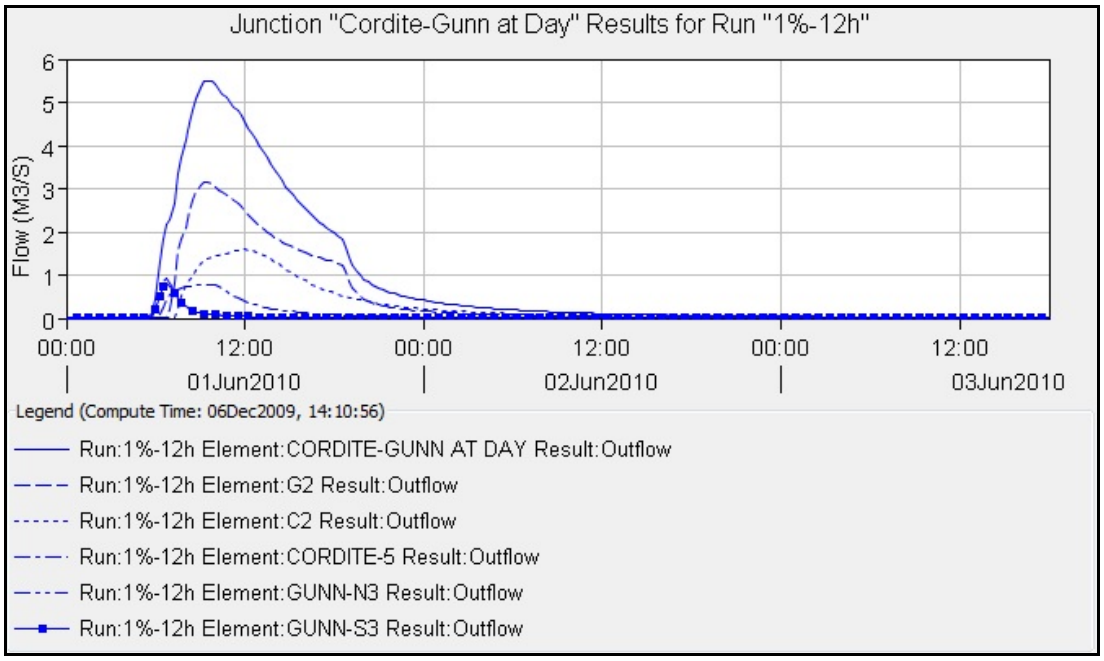
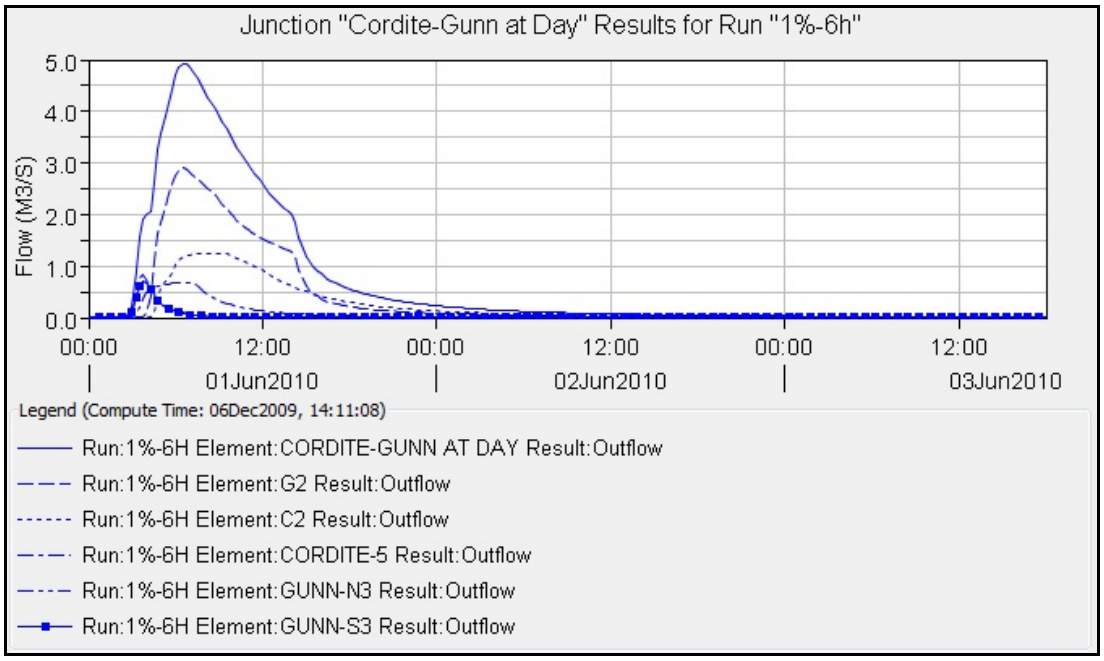


Figure 4. Rainfall-Runoff Model Layout - Cordite and Gunn Road Drains at Day Street



(a)



(b)

Figure 5. Typical Results of Storm Runoff Response Model, Cordite Ditch at Day Street and Gunn Road: (a) 1%-12 hour storm (99 mm), (b) 1%-6 hour storm (89 mm).

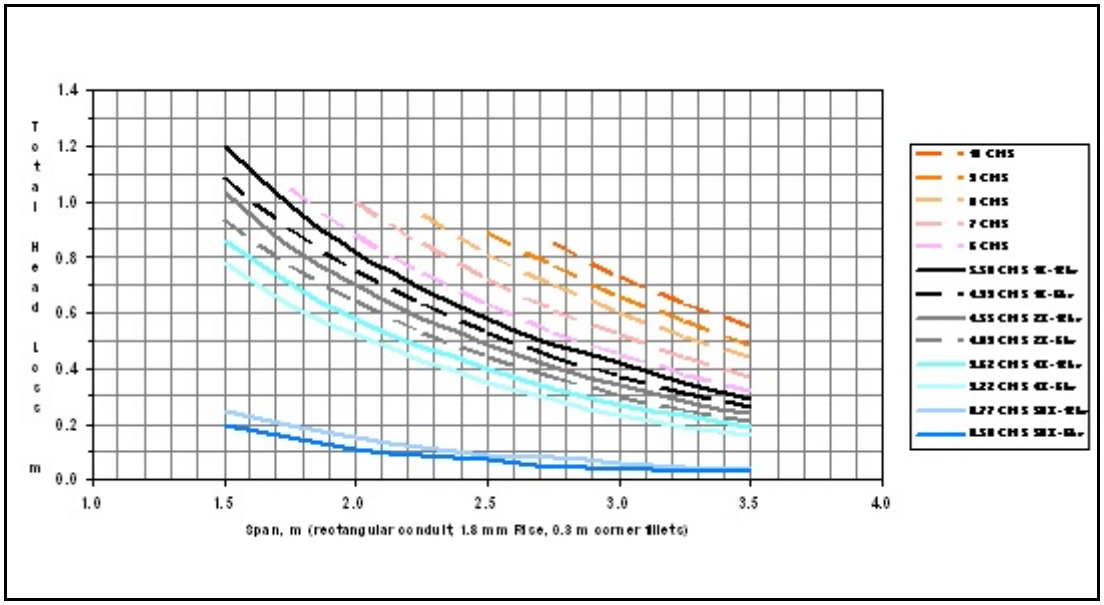


Figure 6. Estimated Total Head Loss across Cordite Ditch Box Culvert at Day Street and Gunn Road for Range of Subcritical Discharges with Open Channel Flow in Culvert Barrel.

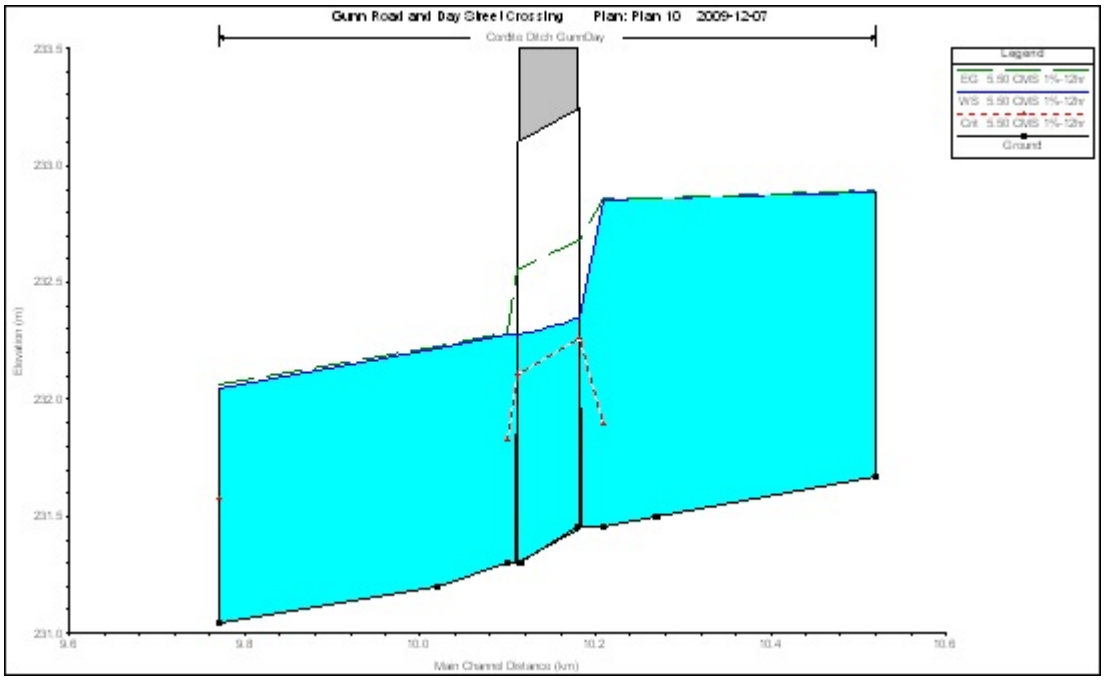


Figure 7. Representation of Estimated Water Surface Profile for 1.8 m X 2.5 m Box Culvert in Cordite Ditch at Day Street and Gunn Road for Discharge of 5.5 CMS.