APPENDIX A

PHASE 1 REPORT (Trunks-Only Drainage System Assessment)

CITY OF
COURTENAY

MEMORANDUM

Date:	January 7, 2019
To:	Ryan O'Grady
cc:	Lisa Butler, Angela Spence, Glen Shkurhan, Ehren Lee
From:	Tim Lutic
File:	3222.0044.01
Subject:	Courtenay ISMP Phase 1: Preliminary Trunk System Performance Assessment and 5 Year Capital Program

Attention: Ryan O'Grady

For the first time, the City of Courtenay is developing a comprehensive city-wide plan to address current and future stormwater issues through long-term capital planning and implementation programs. This report represents Phase 1 of this plan which includes development of a *trunks only* storm system model to identify key deficiencies and potential upgrades. As communicated in the following report, there are significant data gaps and uncertainties that should be addressed and considered before making substantial infrastructure decisions. We also feel that a pragmatic near term program should consider observed performance and infrastructure condition. A preliminary 5-year capital plan is outlined.

However, in addition to design and construction activity, the recommended capital plan includes storm flow monitoring, acquisition of data to resolve gaps, and an allowance for additional CCTV inspection prior to Phase 2 assessment.

We will continue to collaborate with the City to build on this initial stage and work towards a citywide assessment and more advanced strategic plan in 2019.

Sincerely,

URBAN SYSTEMS LTD.

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA T. D. LUTIC # 44700 2019-01-08

Tim Lutic, P. Eng.
Water Resources Engineer

Glen Shkurhan, P.Eng.
Senior Engineer

/tl
Enclosure

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1. Model Development

In collaboration with GeoAdvice, a model was developed using InfoSWMM modelling software to assess the existing and predicted future hydraulic performance of the stormwater conveyance system within the City. Initial scoping of the modelling exercise is outlined in Appendix A, while full details and reporting on model development is included in the memo from GeoAdvice provided in Appendix B.

1.1. Trunks Model Criteria

For the purposes of this exercise, modelling is limited to the primary conveyance trunk network within the City. The trunk network is defined by the following criteria:

- Storm mains greater than 600mm, excluding short segments in downtown area
- Watercourses into which trunk storm mains outlet
- Culvert crossings within trunk watercourses

All surface catchments anticipated to contribute directly or indirectly to the trunk system are included in the model. Subcatchment details are summarized in the map and table in Appendix E

1.2. Data Gaps and Assumptions

Part of this initial modelling task is to identify existing data gaps, of which there are many, and prioritize those which are most critical to the next phases of the work. In order to proceed with Phase 1 trunks only modelling, numerous assumptions or estimations are required. These are made to reflect best interpretation of available background and anecdotal information provided by the City. Much of this information is summarized through a cursory review of historical reports included in Appendix C, as well as a summary of key stormwater infrastructure sites visited in January 2018 included in Appendix D. Additionally, in the absence of reliable field data, many of the hydraulic and hydrologic parameters used in the modelling are chosen based on generally acceptable standard values. These are used without any calibration and are unverified, thus increasing the need for model validation through flow and rainfall monitoring, as well as filling of priority data gaps through field investigation.

Estimations are made conservatively and have been reflected in the modelling. This results in a “worst” case scenario both in hydrology and hydraulic performance. The results should be used only as an early indicator of relative performance and to establish priority among the conveyance system infrastructure. These many data gaps must be reconciled in order to produce an accurate model that can be relied upon for detailed capital planning in the future.

The following list compiles the data gaps and estimations made through preliminary model development:

- Culverts missing from GIS dataset have been excluded from the analysis
- Culvert inlet/outlet structure details unknown in most cases, typical head loss factors are assumed

- Watercourse centerlines, cross sections and invert elevations extracted from LiDAR data; significant approximations were required to achieve a usable geometry
- Watercourse roughness coefficients assumed based on channel features visible from air photos and typical values; to be confirmed due to known vegetation issues in watercourses
- Manhole rims extracted from LiDAR data
- Missing manhole inverts (6% missing) assumed to be 1.5 m depth from rim
- No control structures or storage facilities accounted for in model
- Hydraulic and hydrologic model parameters based on limited knowledge of site conditions and industry standard best practices
- Future scenario based on Official Community Plan (OCP) Land Use Plan
- Deficiency prioritization considers growth nodes from Sanitary and Water Master Plans
- No base flow accounted for in model
- Missing storm main diameters (3% missing) estimated based on upstream/downstream diameters
- Some "virtual" nodes and gravity mains added to model for connectivity
- Subcatchment width calculated by dividing area by longest possible flow length

These data gaps have varying impacts on the reliability of model results and many are discussed throughout this summary report.

Due to the extent of assumptions made for the trunk watercourse geometry, these are currently excluded from the performance ratings. Ratings are only assigned to the storm mains and culverts at this time.

1.3. Model Scenarios

This analysis is applying the new criteria and precipitation data in the updated Subdivision and Development Servicing Bylaw 2919.

Imperviousness for existing condition is calculated using the City's existing Zoning maps, with imperviousness values assigned to each zoning type in general accordance with Master Municipal Construction Documents (MMCD) guidelines, tailored to suit our understanding of the City's zoning and land use descriptions. In subsequent iterations of modelling, the existing imperviousness values can be further refined through review of air photos.

Future scenarios are modelled using the same design storm distribution as applied to the existing scenario but include the 15% increase to intensities to account for climate change. The OCP Land Use Map is used to determine potential future land use, to which we have applied the same imperviousness parameters as to the equivalent existing (zoning) land uses. Future zoning designations from the Transportation Master Plan were initially planned to be used for the future model scenario, however these transportation zoning parcels are not discrete enough making their application inappropriate for this study. Future land uses from the Water and Sewer Master Plans were also not able to be used since these are focused on population growth. In terms of the stormwater system, population growth often does not directly correlate to changes in runoff.

Until 1998, the City's stormwater design criteria only required the minor system to accommodate the 5 year flow. Much of the infrastructure included in the model would have been constructed prior to the current 10 year minor system conveyance requirement, therefore a significant amount of surcharging is expected to appear in the modelling.

1.3.1. Design Storm Discussion

The updated Subdivision and Development Servicing (SDS) Bylaw and the Modified Chicago Design Storm has been a topic of discussion for the City since its adoption. It is more conservative than previously applied distributions, but selected based on projected future rainfall patterns due to climate change.

The 24 hour Modified Chicago storm distribution has several benefits

- Reflects all intensities from the Intensity-Duration-Frequency (IDF) curve during a rain event for a given return period, so a single 24 hour hyetograph can be used to design all drainage system components. This simplifies analysis and review.
- It accounts for antecedent rainfall prior to the peak intensity.
- It is a generally accepted design storm, used by municipalities in both the US and Canada.
- Contributes to conservative (lower-risk) designs.

The conservative nature of the Modified Chicago storm has historically made it more suitable for regions that experience convective storms. While not historically significant in this region, current climate change research indicates that with warmer temperatures more convective storms can be anticipated on the BC coast. The current prediction is that for shorter duration storms, peak intensities could increase at a greater rate than overall daily rainfall. This suggests that historical design storms may need to be replaced by storms with higher peaks such as the Modified Chicago storm.

For comparison, a 1 hour Atmospheric Environmental Services (AES) distribution storm was modelled for the existing scenario. This distribution is more in line with the approach taken prior to adoption of the current bylaw, and is a valid comparison for conveyance capacity testing since the short duration peak is embedded in the peak of the Modified Chicago storm. The resulting performance summary map is included in Appendix F and illustrates a similar level of deficiencies to that of the Modified Chicago storm. This provides a level of confidence in the chosen design storm, however it is still worthwhile to validate the appropriateness of the chosen design storm in the context of this study.

The application of the Chicago storm, particularly in combination with an increase intensity is intended to future proof infrastructure decisions and investment. It is not to suggest that risk today is significantly higher than it was yesterday. Climate change forecasts are currently projected for year 2050 and 2080 with varying confidence levels. Stormwater infrastructure should have a life span of 75 years, so anything installed in 2020 is expected to provide the desired level of service to the end of the century. The implication of this forward-looking criteria on existing system performance is expected to be substantial and will need to be taken into account as the ISMP progresses. Deficiencies are highlighted in the trunk system model results discussed below, and will be studied in more detail as the next stages of modelling and analysis are conducted.

In order to incorporate the updated design criteria into the City's existing infrastructure, a key goal of this ISMP is to develop a thoughtful and pragmatic stormwater strategy that accommodates growth and allows gradual adaptation to the more stringent stormwater criteria in the interest of the City's long term benefit. In future stages of this ISMP process we will look further into acceptable levels of service and risk to failure. Discussing the City's tolerance to risk, and desire for future proofing near term decisions, will need to be part of that process.

1.4. Assessment Criteria

Hydraulic capacity of the trunk conveyance system is assessed based on a combination of hydraulic capacity and surcharge depth. An overall Likelihood of Failure (LoF) rating from 1 to 5 is assigned to each segment of storm main and culvert crossing accounting for both hydraulic capacity and surcharge. These ratings are derived and summarized as follows:

Table 1.1: Hydraulic and HGL Scoring Criteria

Criteria	Result
Hydraulic Capacity (q/Q = peak flow / full pipe flow)	
q/Q < 1	A
q/Q >= 1	B
Hydraulic Grade Line (HGL)	
HGL < Crown Elevation	A
Crown Elevation <= HGL < Ground Elevation	B
HGL >= Ground Elevation	C

Table 1.2: Capacity LoF Ratings

Capacity LoF	Hydraulic	HGL	Description
1	A	A	Conduit performing as designed
2	A	B or C	Adequate capacity, downstream condition causing backwater
3	B	A	Marginal capacity
4	B	B	Capacity exceeded and surcharging likely
5	B	C	Capacity exceeded and flooding likely

2. Model Results

Maps provided in Figures 1 to 6 indicate the performance ratings of the trunk system for both existing and future scenarios in accordance with the criteria described in Tables 1.1 and 1.2 above. These maps provide an overall idea of system performance, however for nodes indicating flooding, the maps do not indicate the degree of flooding (volume, rate). Prioritizing deficiencies will involve a detailed review of individual pipe capacity and surcharge levels to determine the degree of surface flooding modelled, as well as the location of constrictions since node flooding may be due to backwater caused by downstream conditions.

Particular attention is paid to the 10 year storm maps, as this is what the minor conveyance system is intended to accommodate according to the current and previous SDS Bylaw. The 2 year storm has been modelled to illustrate areas which are more severely undersized, or perhaps areas which require model validation and may be prioritized for flow monitoring. The 100 year storm shows many pipe deficiencies as expected, and is more useful for reviewing road crossing culvert capacity (intended to convey 100 year major system flows) and for overland flow path routing.

A conservative assumption in modelling that can be a significant cause of incongruence between modelled and observed condition is that catchment runoff is efficiently captured. In reality, particularly in older development areas and where roadways and parking lots do not have continuous curbs, it is often that storm drain inlets are insufficient. Therefore, with basic site grading and inlet improvements runoff flows may increase.

2.1. Notable Existing Model Deficiencies

Several deficient areas are noted in this trunk system model according to the current design criteria, as seen in the Existing System 10 Year Storm results in Figure 2. For this Phase 1 analysis, the focus for the near-term capital program is placed on pipes with an LoF score of 5.

It is important to note that although the model results show many instances of flooding, this does not necessarily mean that surface flooding would have been witnessed at these locations at any point in the past. As discussed In Section 1.3.1, the design storm used in this model is a conservative, high intensity event.

As part of the data gaps resolution and model calibration process, we recommend that the model be run for observed historic significant storm events and the results compared against anecdotal information.

The following subsections discuss areas exhibiting the poorest performance and most extensive theoretical flooding under the Existing 10 Year scenario.

2.1.1. Gravity Mains

💧 **Woods Ave**

The Woods Ave storm system catchment is almost entirely made up of residential lands and some recreational. The trunk storm sewer runs from 10th St at Urquhart, connecting with Woods Ave and discharging into Puntledge Park at the Woods Ave outfall. The only pond within this area shown in the GIS dataset is at the Puntledge Park Elementary School, which is not believed to offer significant attenuation. No new developments are expected in this area according to the OCP Land Use Plan.

Flooding in this system appears in the model at the upstream end on Urquhart Ave as well as on Woods Ave. Some flooding may be due to flatter pipe slopes toward the downstream end of the Woods gravity main.

Infrastructure records indicate this is an asbestos cement (AC) system which may or may not be in good condition. AC pipe longevity is sensitive to soil chemistry. This has been identified as one of the high priority systems near term, subject to a condition assessment. This assessment should begin with video inspection, but may also involve a coupon sample of the pipe as AC tends to go soft in some soils.

💧 **Willemar Ave**

The Willemar Ave trunk system is the longest reach of trunk sewer in the City, running along Willemar Ave from 10th Street to the outlet at the Comox Valley Parkway. This portion of the system collects runoff from a large catchment of mainly residential land. The GIS dataset does not show any stormwater management facilities offering attenuation to the storm system within the catchment.

The majority of problems appear in the model at the upstream end of the system, likely influenced be a constriction on Willemar Ave from a 1050mm diameter pipe to a 900mm diameter pipe. Several manholes upstream of this location on Willemar Ave, as well as 13th St, are showing signs of significant flooding. This pipe sizing should be confirmed and the transition manhole inspected.

Infrastructure records also indicate that this system is very flat (low gradient) with corrugated metal and some wood stave pipe. It is our understanding that the City has previously undertaken remedial works in this system, however the extent of which is not clear. This system is identified as one of the high priority systems near term and requires comprehensive investigation, including both configuration and condition assessment.

19th St Outfall

The 19th St Outfall trunk system is in a primarily residential area with no stormwater detention facilities indicated in the contributing catchment. The OCP Land Use Plan does not indicate any change. The system collects runoff from as far west as Willemar Ave, discharging to the Puntledge River at 19th St.

Model results show several instances of flooded manholes; the most severe location being at the upstream end near Urquhart Ave and 21st St. Given no projected growth, it is recommended that model calibration be conducted ahead of firm replacements.

Infrastructure records indicate this system is largely a wood and corrugated metal pipe system and if so may be at the end of its life span. Subject to a condition review, this has been identified as one of the high priority systems near term.

26th Street, 29th Street and Cliffe Ave

The catchment near Driftwood Mall consists mainly of commercial, residential and recreational lands and runoff is conveyed to a marine outfall off Mansfield Dr, however there is an adjacent outfall at 29th Street which may or may not have some interaction and should be confirmed. Land Use Plans do not indicate significant changes planned in the area, however 2018 Development Applications show potential for some development. No stormwater ponds are operating in the contributing catchment.

The manhole showing the most severe flooding is on 26th St between Fitzgerald and Cliffe Ave. At this manhole, the gravity main transitions from a 900mm diameter pipe upstream to a 600mm diameter pipe downstream, which is a considerable constriction and likely cause. This pipe sizing should be confirmed, and the transition manhole inspected.

While infrastructure mapping shows some sections of PVC and concrete pipe, the majority of this trunk system is AC and corrugated metal, and therefore identified as one of the priority areas near term, subject to monitoring and a condition assessment.

Headquarters Rd

The storm system at Headquarters Rd runs through the Comox Valley Seniors Lodge property and daylights across Headquarters Rd, making its way to the Tsolum River. The catchment includes a mix of residential, institutional, and commercial lands and has been conservatively estimated to extend north into recreational lands. The catchment includes several small stormwater management ponds in the Seniors Lodge property. The OCP Land Use Plan doesn't indicate any significant changes to land use.

Manholes at the downstream end near the outlet are predicted to experience surcharge and flooding which may be influenced by a reduction in pipe size from 750mm to 675mm. This reduction should be confirmed in the field and the condition of the transition identified. A reduction in pipe size can be successful if properly constructed, however can be a big source of hydraulic losses if not.

Flooding in this area would likely affect the residential properties west of Headquarters Rd, however topographic information will need to be studied in greater detail to assess the specific overland flow path and extent of likely impact.

A manhole on the Seniors Lodge property is also showing potential flooding, however far less severe than near the outlet. This manhole is at the outlet of a stormwater management pond, which is not yet represented in the model. It is recommended that the pond be represented before judgement can be reached on the adequacy of this sewer.

This is a relatively small system and not considered one of the higher priority areas near term.

Sandwick Park

The trunk system originating on a portion of the North Island College site drains under Muir Rd, discharging into Sandwick Park and eventually Portuguese Creek. The catchment includes primarily single-family residential lands and a large portion of the forested area adjacent to the College. The current zoning for a portion of the forested area is Single Family Residential, indicating that there may be potential for growth within the catchment. No ponds are present in the catchment according to the GIS dataset.

Flooding occurs in the model at the downstream end of the system near Sandwick Park, as well as at the upstream end near North Island College. The gravity main throughout this portion of the system is PVC and 600mm in diameter. Causes of theoretical flooding at this location may be due to the conservative estimation of the contributing catchment. We recommend that monitoring and model calibration be conducted prior to recommendations for capital improvements.

This is a relatively small system and given that it consists of newer pipe materials (PVC) this is not considered one of the higher priority areas near term.

North Lerwick Rd

The Lerwick Road storm sewer near Veterans Memorial Parkway was studied in detail earlier this year by Urban Systems (Lerwick Road Storm System – Monitoring and Analysis Summary, USL, July 2018). Model results herein are yielding similar results to the detailed study.

South Lerwick Rd

This section of the stormwater system collects runoff from the areas surrounding Lerwick Road between Hawk Dr Park and Idiens Park. Storm trunk mains run north along Lerwick Road and down Hawk Dr, eventually discharging into the Hawk Dr and Glacier View Ponds. The area is primarily comprised of residential development with no significant changes anticipated. Several manholes show minor flooding in the model results, however the most significant flood volume is seen on Lerwick Rd. Flooding in this area would likely travel along Lerwick Road and may put homes at risk. There is one storm pond indicated at the upstream end of the system on Nairn Pl. which should be added to the model and performance rechecked through model calibration.

This system is one to monitor and not considered high priority near term.

Comox Valley Hospital

The outlet of the Comox Valley Hospital site is showing flooding, however it is believed that this is due to the model omission of a known underground stormwater management reservoir attenuating up to 100 year flows. On subsequent model iterations, this site is expected to perform much better due to the stormwater facility.

This system warrants resolution of data gaps and monitoring and not considered high priority near term.

Malahat Storm Park

This portion of trunk storm main connects a portion of North Island College on Ryan Rd to the City's storm detention pond at Malahat Dr/Mallard Dr. The catchment is primarily residential, but includes a portion of North Island College at the upstream end. One storm pond is shown in the College property which we recommend be added to the model. No changes within the catchment are indicated in the OCP Land Use Plan.

Without accounting for the detention pond, several of the manholes in this system are showing flooding. The GIS dataset indicates flattening pipe slopes near the outlet, which may be causing a backwater impact. The profile of this main should be reviewed in greater detail.

This system is recommended as one to further investigation and monitor, but is not identified as high priority near term.

1st Street

The 1st St storm main is a small section of trunk system between Rod and Gun Rd and Willemar Ave which also discharges at Puntledge Park. The catchment is comparatively small and consists mainly of residential lands, which is not expected to change in the future. No stormwater ponds in the catchment are evident in the GIS dataset.

Several storm mains in this short stretch are exceeding capacity resulting in flooding, which we recommend be first reaffirmed through monitoring and model calibration. Infrastructure records indicate this system is newer PVC material, therefore is not considered a high priority system near term.

- **Crown Isle**

The Crown Isle Development is a significant area for consideration by the City. Modeling shows flooding under the 10 year event at Crown Isle Dr near Dover Pl. During a field visit with City staff in January 2018, it was pointed out that a weir had been installed in one of the manholes on Crown Isle Dr to alleviate flooding to the south. This feature is not currently reflected in the model.

The model at this time does not account for the extensive network of stormwater controls within the Crown Isle development as analyzed and reported by Koers & Associates. It is recommended that future analysis of this system apply discharge hydrographs as reported or adopted from the detailed analysis conducted by Koers & Associates. It is also recommended that a long term hydrometric monitoring station be established downstream of the Crowne Isle development and temporary monitoring on the south Lerwick Road trunk sewer.

2.1.2. CULVERTS

The inventory of culverts is currently poor; therefore, the assessment of culverts is lacking. The lower portions of Glen Urquhart Creek, Morrison Creek, and Portuguese Creek in particular have a number of road crossing culverts not currently accounted for.

Of those that have been assessed, performance under the existing 10 year and 100 year events are good to moderate. The performance of roadway culverts can be significantly influenced by inlet conditions, which is not currently inventoried. In addition, the acceptable level of service may vary to suit the significance of roadway and public safety. It is unknown currently what criteria, or level of service, was applied to each culvert, but it is typical today that all road crossing culverts be sized for the 1:100 year event, particularly for roadways classified above "Local".

It is our understanding that poor culvert conditions are common in the City, and therefore may be more influential to the capital plan than capacity. Proper operation and maintenance of culverts are vital beyond just stormwater conveyance, as their failure can significantly impact other infrastructure, public safety, environment, property access, etc. We recommend that road crossing culverts be considered high priority in the near-term capital program. This includes completing the inventory, a condition assessment, updating the hydraulic performance assessment and redefine a priority-based replacement program.

Figure 1: Existing 2-Year Results

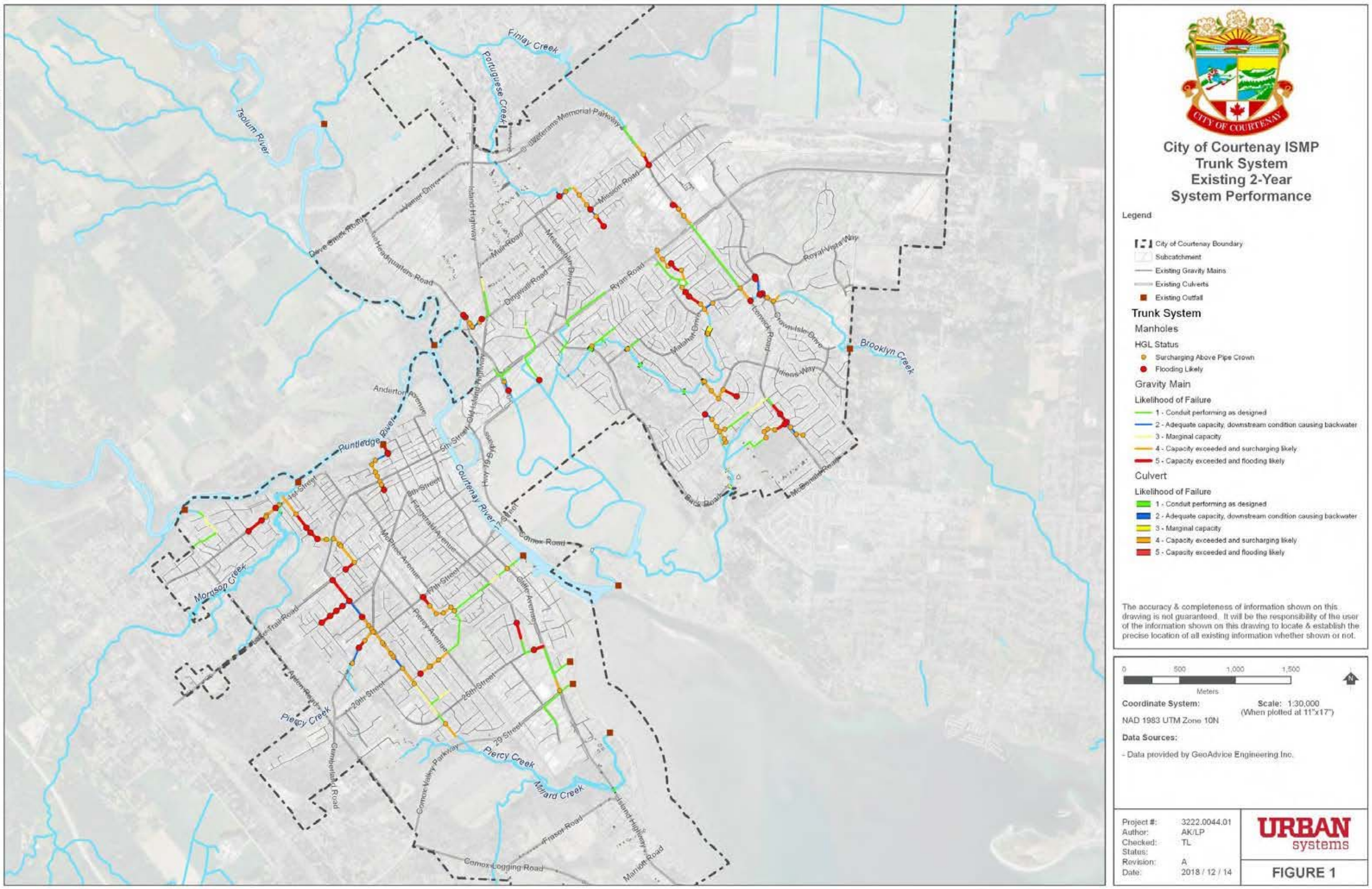


Figure 2: Existing 10-Year Results

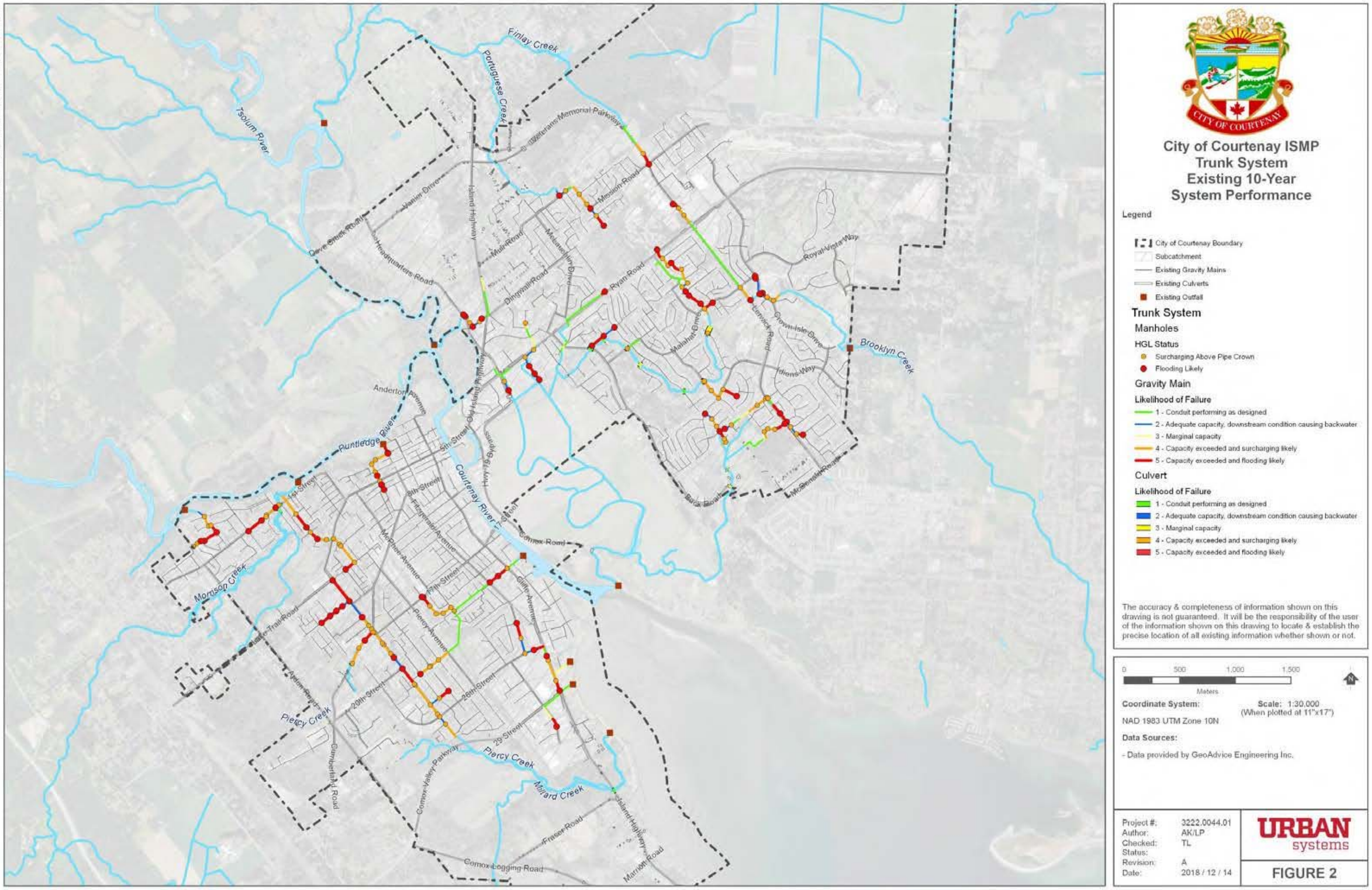
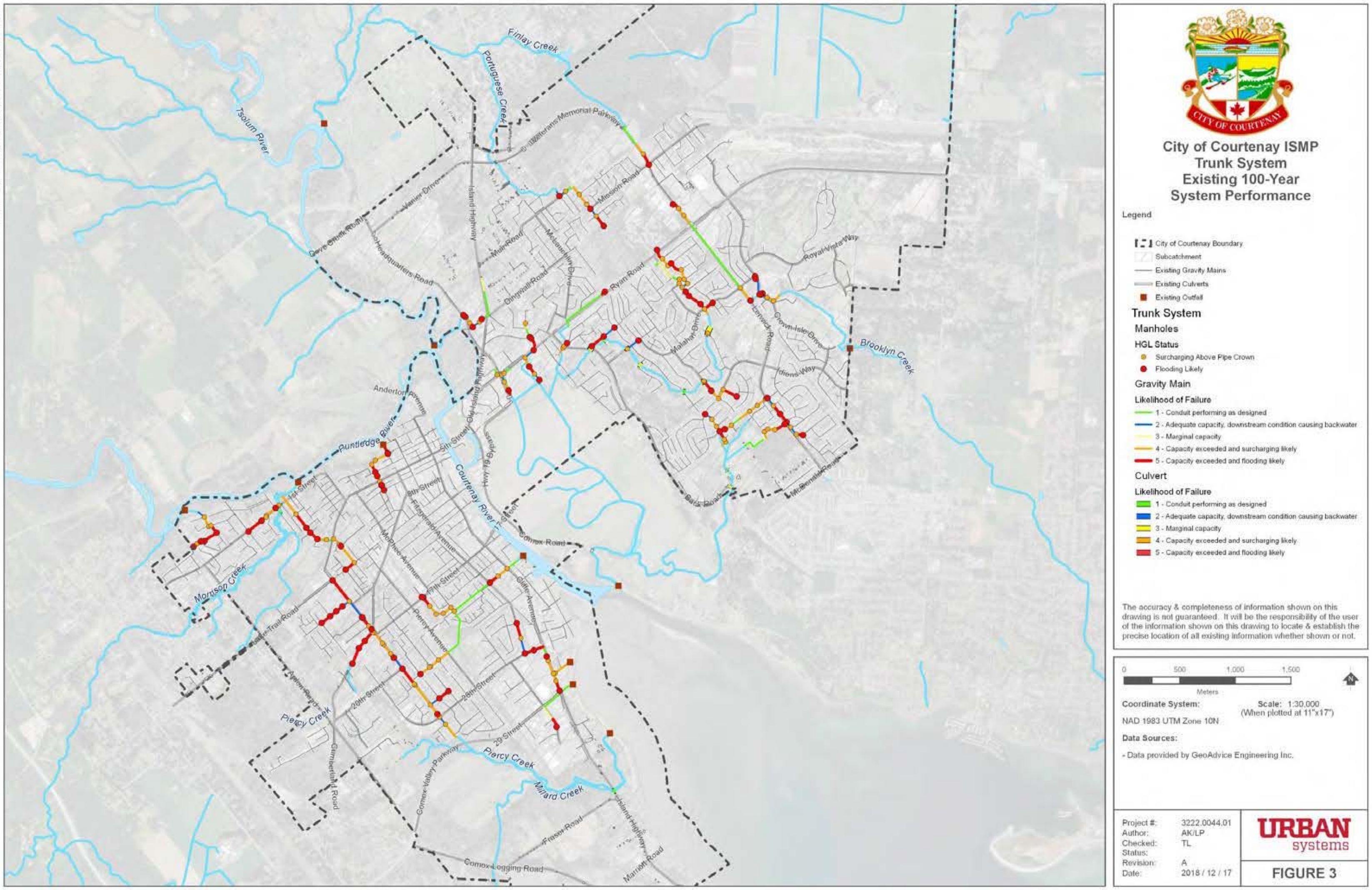


Figure 3: Existing 100-Year Results



2.2. FUTURE DEFICIENCIES

As expected, the degree and magnitude of deficiency and flooding can be expected to increase into the future, most broadly caused by projected climate change, but also caused by land use change in some catchments. However, at a trunk scale the pattern of system failure is relatively similar in both the existing and future condition scenarios.

The results presented herein demonstrate the relative significance development and climate change may have, however at this time future conditions have not considered stormwater controls being applied within growth areas. The application of controls remains advisable for all new development.

It is understood that the City has recently initiated a review of its DCC program which will include scope to identify the program and portion of costs justifiably applied to development.

Figure 4: Future 2-Year Results

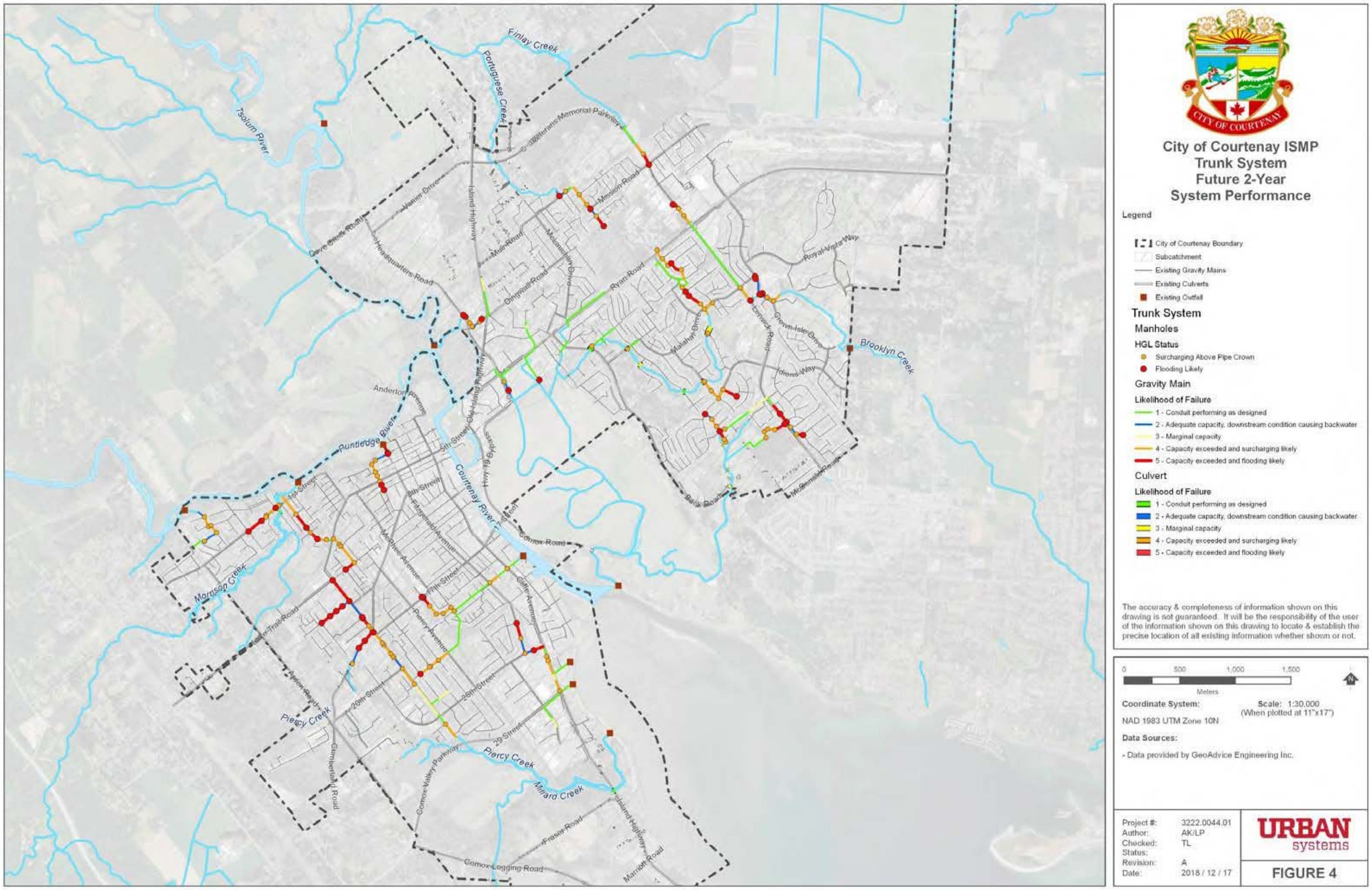


Figure 5: Future 10-Year Results

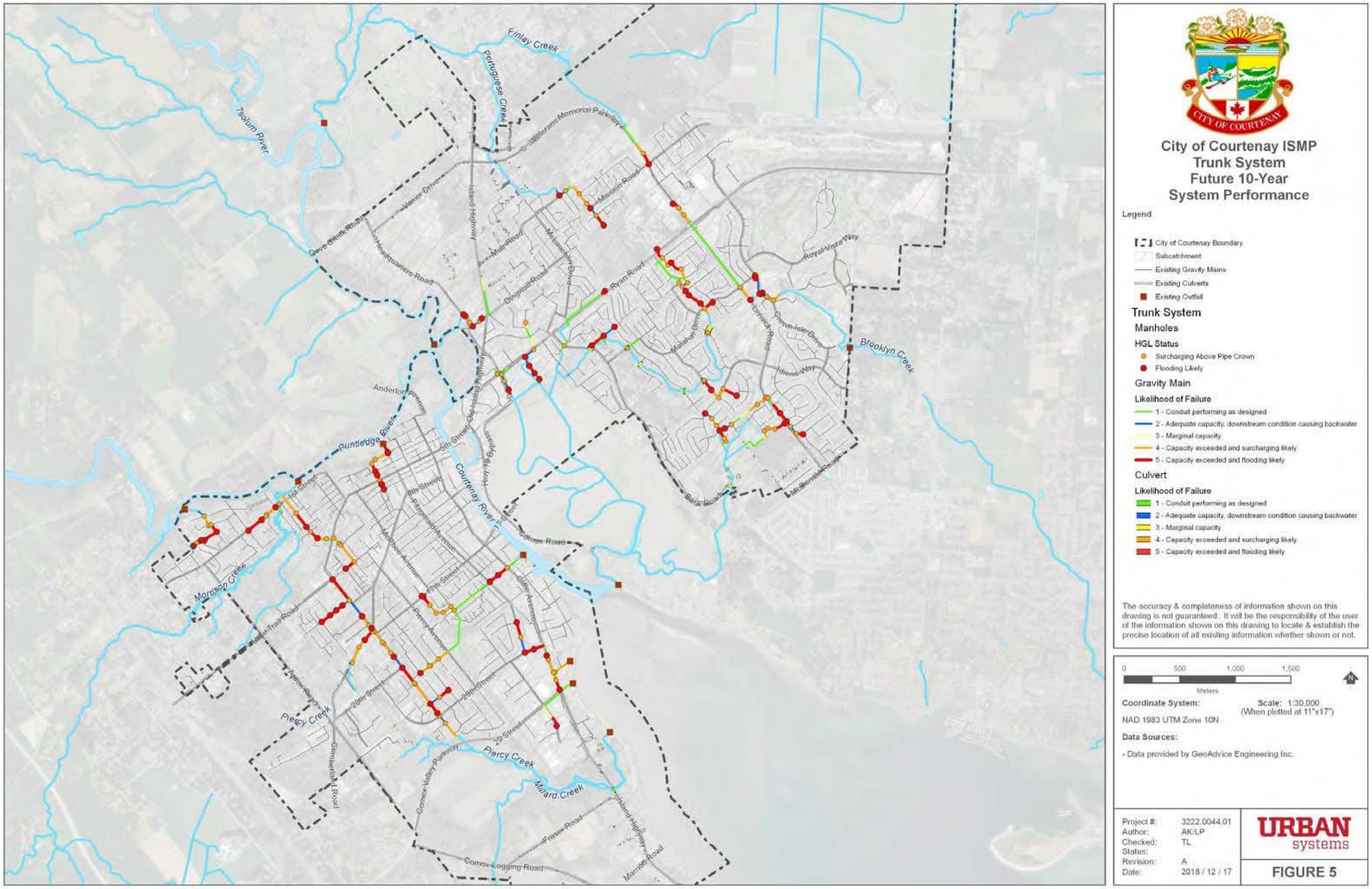
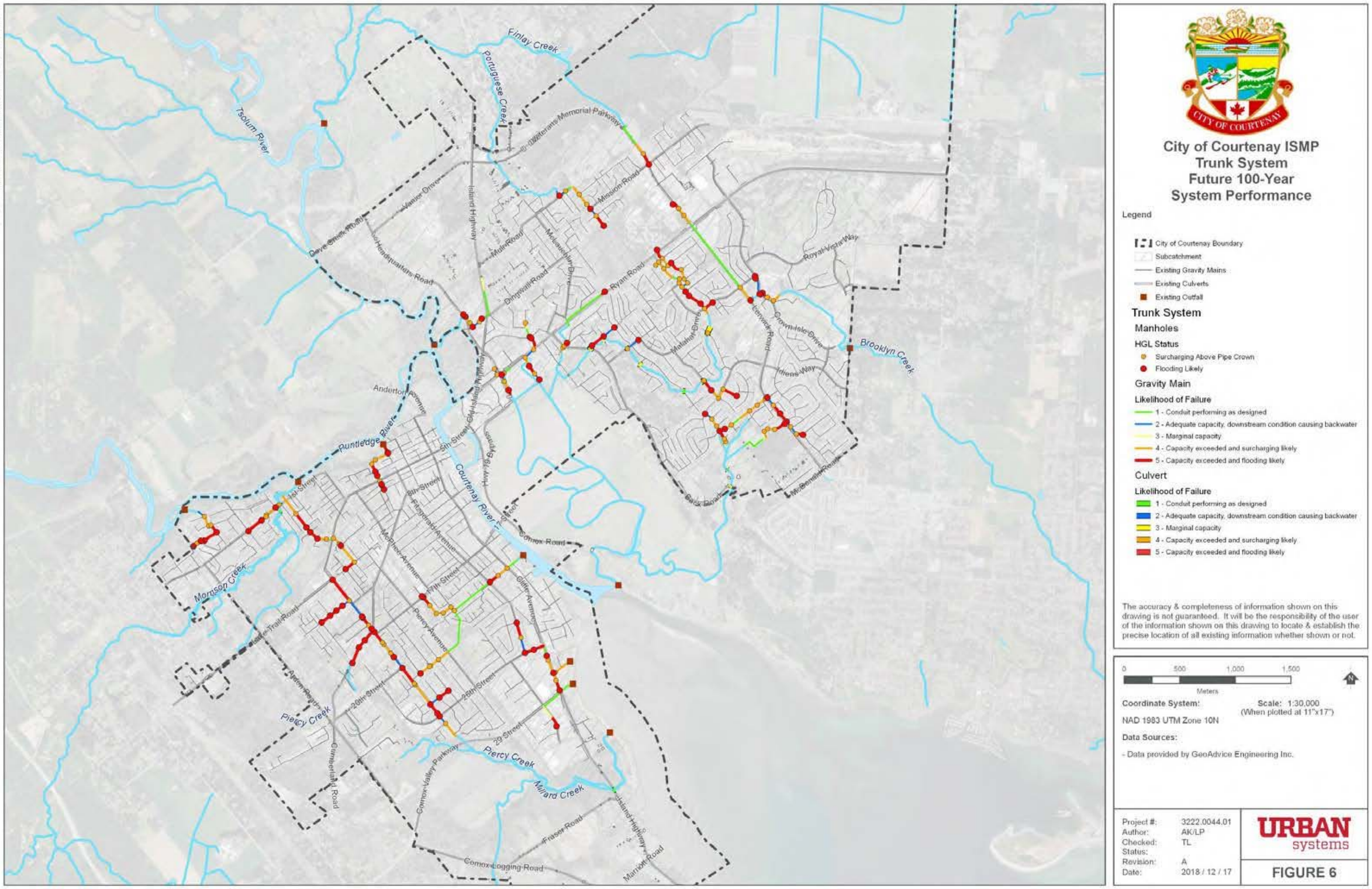


Figure 6: Future 100-Year Results



3. Recommendations

A comprehensive infrastructure program is "alive" and should be regularly updated by new information, community needs and values, political direction, risk, community growth, financial capacity, among others.

Analytical models (the focus of this study) are an important tool to predict system capacity, however an accurate prediction requires significant data and information. For this trunk study, information is currently lacking, therefore is the important first step of a long-range process. Refinements are required through resolution of data gaps.

Hydrologic processes are complex and highly variable. Modeling involves many assumptions, estimates, and approximations that should be calibrated to observed conditions. This process starts with monitoring.

In a mature, aging area it would be unwise to build a program purely based on a theoretical prediction of hydraulic performance. Rather, condition and remaining life should be considered.

Based on the above, our recommendations are formulated around three fundamental components:

1. Near term infrastructure renewal decisions (capital plan) driven first by condition and observed failure, supplemented by predicted hydraulic performance.
2. The acquisition of additional infrastructure inventory data to resolve geometric data gaps.
3. The acquisition of flow and precipitation data to support future model calibration

3.1. Priority Systems

Based on the foregoing sections, four systems have been identified as high priority near term, as highlighted in Figure 7:

1. Woods Avenue (1.0 km)
2. Willemar Avenue (2.7 km)
3. 19th Street (1.8 km)
4. 26th Street, 29th Street, Cliffe Avenue (1.5 km)

The total infrastructure length of these systems is 7 km.

These are priority systems that are likely to involve design and construction improvements long term, however are subject to condition assessment. All systems, priority or not, are subject to further investigation and monitoring.

3.2. Near Term Capital Plan (2019 – 2024)

As a trunks only model, despite having incomplete culvert data, over 18 kilometers of lineal pipe infrastructure (excluding channels) is included in this assessment. The weighted (by length) average pipe size of this trunk system is 800 mm in diameter. Assigning a typical planning level unit cost of $2.50 per mm m (including engineering and contingencies) this equates to approximately $36M of infrastructure value. Highlight statistics of this trunk infrastructure is provided below in Table 3.1:

Table 3.1 – Inventory of Trunk Pipe Material

Pipe Material	Total Trunk Length	% of Total	Typical Age
Asbestos Cement (AC)	1,500 meters	9	50 to 60 years
Wood	1,000 meters	5	60 to 70 years
Corrugated Metal Pipe (CMP or CSP)	7,300 meters	40	40 to 50 years
Concrete	800 meters	4	30 to 40 years
Plastic (PVC or HDPE)	7,500 meters	41	15 to 30 years
Unknown	200 meters	1	n/a
Total	18,300 meters	100	

We understand that the City has some understanding of infrastructure condition, but not in a comprehensive way. We understand that culverts are particularly poor. In absence of field data, age and material type is commonly used as a proxy for condition. Approximately 50% ($20M in capital value) of the trunk infrastructure is over 40 years of age and of a material type that may be nearing the end of its life expectancy. This infrastructure would have been done in an era with different criteria, different climate, and different construction practices.

Given the potential enormity of capital reinvestment required within the City, the recommended near-term capital program (1-5 years) is formulated on:

- ✓ **Priority 1 – Known condition and known performance.**
- ✓ **Priority 2 – Anticipated condition based on age and material type.**
- ✓ **Priority 3 – Theoretical hydraulic performance.**

Broader considerations are required for developing a long-range capital program, which must be better informed by new information, as described in the sub-sections below.

For hydraulic performance, recommendations at this time only consider conduits that scored an LoF of 5 (capacity exceeded and flooding likely under a 1:10 year event).

A detailed summary of known pipe material, age, and theoretical hydraulic performance of the trunk system is included in Appendix G.

3.2.1. Financial Capacity

The capacity for the City to finance the capital program is an important consideration. We understand that in recent years the City has spent in the order of $350,000 to $500,000 per year on drainage infrastructure, most commonly on culvert replacements. The City recognizes the need to increase spending. Water and sanitary programs have also migrated upwards and are currently in the $1.5M to $2M per year range. Given the evident need of reinvestment in the drainage system, we recommend a similarly sized program to water and sanitary, including construction, monitoring, and field assessment work. The next two years will involve a higher proportion of monitoring, field assessment, data collection and revised study. As such, for planning purposes we have developed a construction program over the next five years as provided in ***Table 3.2***:

Table 3.2 – Recommended Near Term (2019-2023) Construction Program

Year	Construction Value	Approximate Length of Work (see notes)
2019	$1.5M	500 m
2020	$1.5M	500 m
2021	$2.0M	670 m
2022	$2.0M	670 m
2023	$2.0M	670 m

Note 1 – Length based on an estimated average of $3,000 per lineal meter, including engineering and contingencies, but excluding significant conflicts with other utilities or full road width pavement restoration.

Note 2 – Road crossing culverts tend to have a higher unit replacement rate, typically ranging between $4K and $10K per meter depending on the characteristics of the site and design.

Note 3 – This program is preliminary based on current information and subject to change through new information.

As noted in subsection 3.1, the total length of four priority systems identified for near term capital re-investment is 7 km, far exceeding the 3 km total estimate defined in Table 3.2 above for a 5 year, $9M total capital program.

It is not possible at this time to recommend specific pipe reaches to be reconstructed, as further investigation described herein is required.

Figure 7A – Prioritized Capital Works Locations

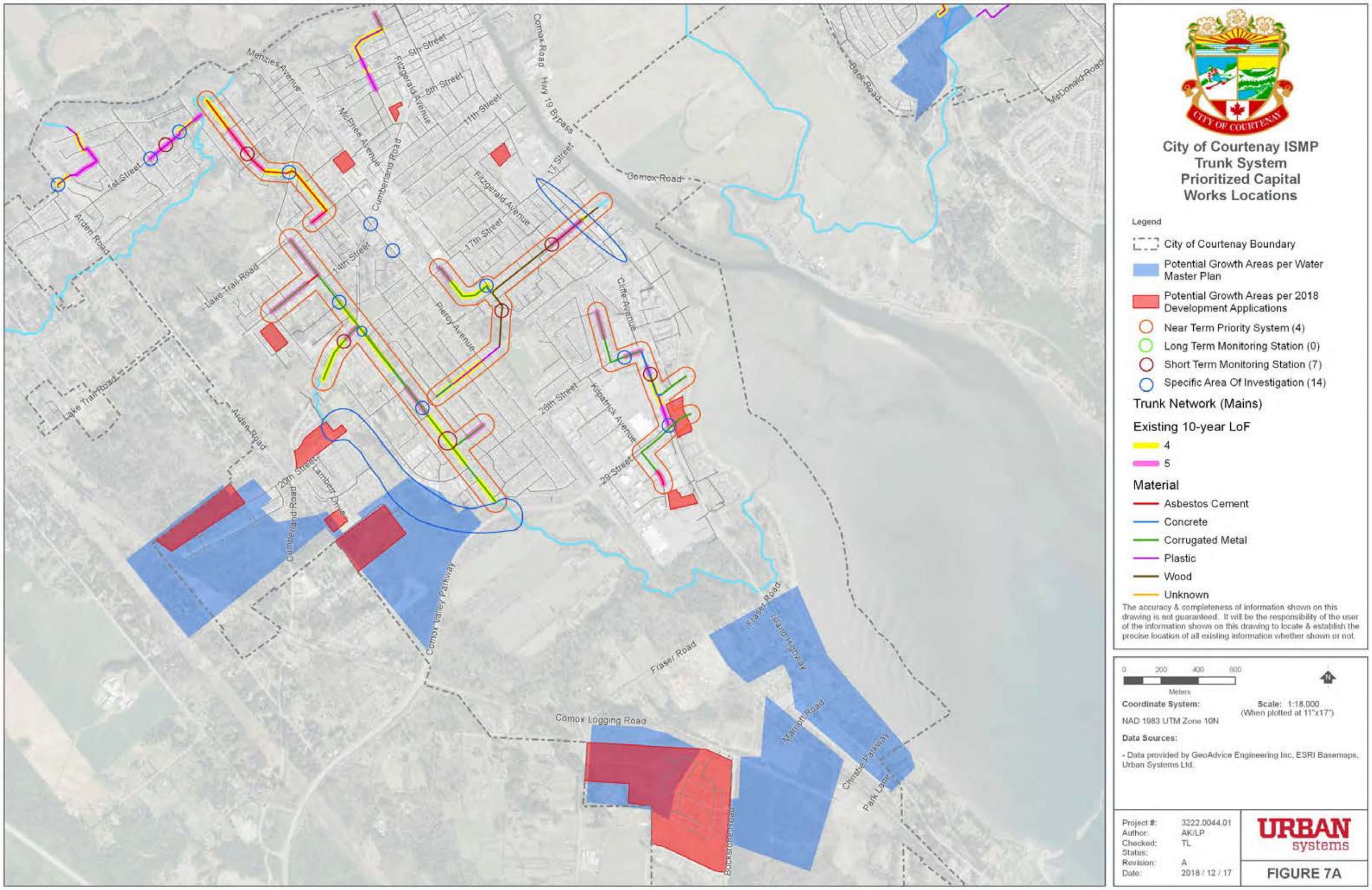
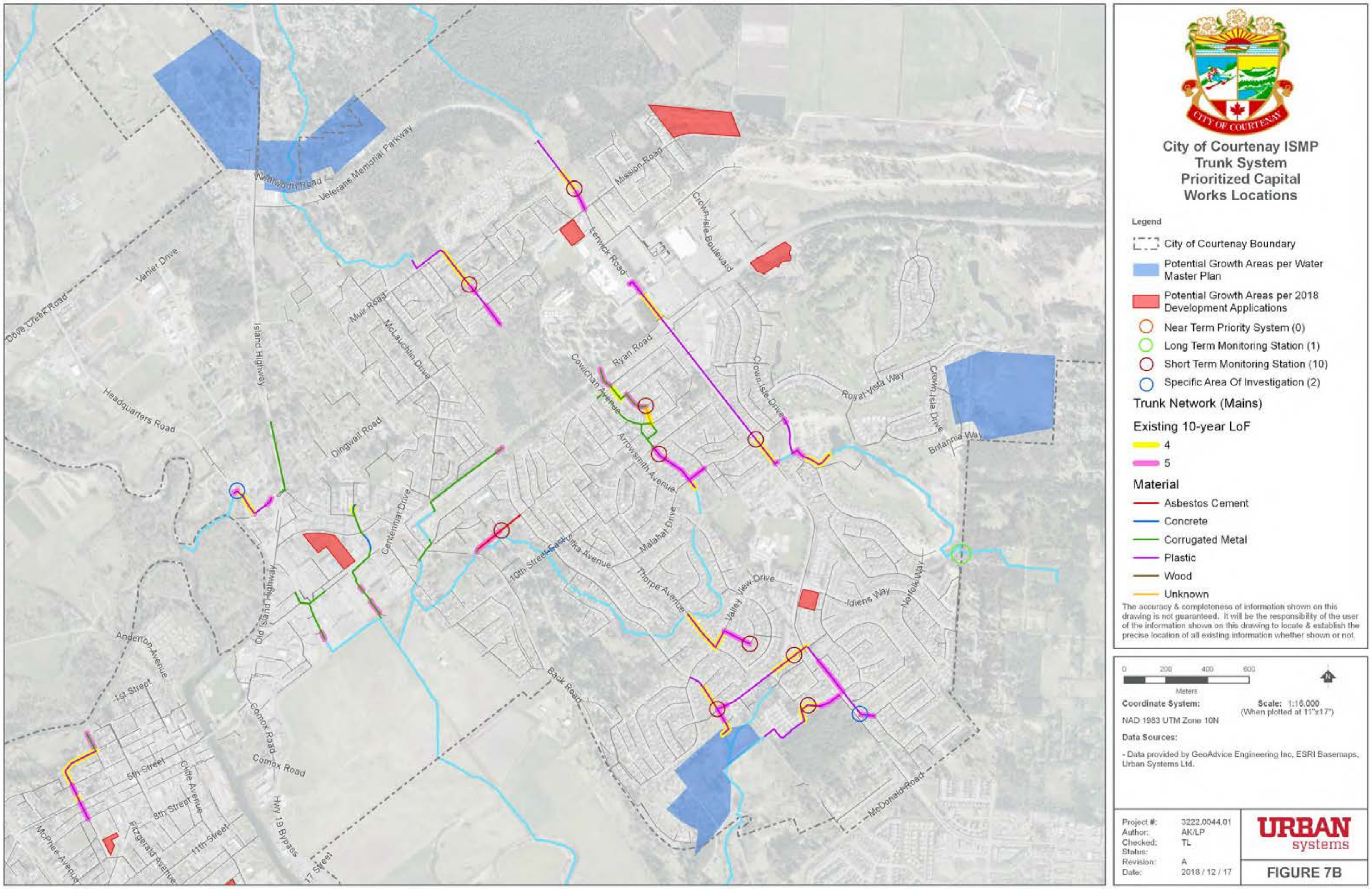


Figure 7B – Prioritized Capital Works Locations



3.3. Hydrometric Monitoring

Hydrometric monitoring (flow, level, precipitation) is recommended as an important component of the near-term capital program to enhance understanding of current hydrology and system performance. This will support model calibration, reduce uncertainty, and better define risk and program priorities.

Numerous monitoring sites have been identified in Figure 7, however for practical reasons we suggest isolating 2018-2019 monitoring to 10 sites for 4 months each.

At this time, study is focused on system capacity during peak conditions. The period of monitoring with the highest chance of capturing a significant rainfall event is November through February (4 months). For the purposes of evaluating environmental conditions and developing rainwater retention targets and tracking change there is benefit to capturing long-term data, but has significantly higher cost. Cost of a long-term program is also governed by the telemetry and databased system the City wishes to establish. Many municipalities are using the service offered by FlowWorks. (http://www.flowworks.com/)

A four-month temporary monitoring program is worthy of equipment rental with a full-service provider. More than four months is worthy to consider equipment purchase.

For planning purposes, the unit cost for a temporary station is $2,000 per site per month including equipment, installation, removal, reporting, and an allowance for traffic control. For a four-month program, the cost becomes $8,000 per site.

For a permanent installation, the cost is estimated at $10,000 to $15,000 depending on a number of factors for installation alone. They cost may be higher in open water courses were a primary device (e.g. culvert, flume, weir, etc.) is not available. There are additional ongoing maintenance and monthly data management costs.

At this time, we offer consideration for 9 short term stations to be installed over this coming winter season ($72,000), combined with 1 permanent installation ($15,000 plus monthly maintenance and database costs). Specific locations will be subject to site investigation and agreement with the City on priority systems.

In round planning numbers, a 10 site program is $90,000 over the coming year. Additional permanent installations may be recommended through the phase 2 study in 2019 after the collection of near term data to allow phase 2 model calibration and refined decisions.

3.4. Resolving Data Gaps

Performance analysis is highly dependent on having adequate geometric information about the system. There are a significant number of data gaps that should be filled using various sources and methods, a summary as follows:

1. Representative cross sections of relevant watercourses obtained through field survey
2. Missing road crossing culverts obtained through field survey
3. Critical storm sewer inverts and size transitions obtained through field survey
4. Storage facilities through review or record drawings and supplemented by field survey
5. Confirming system configuration through field survey
6. Compile soils and hydrogeology information for enhanced catchment analysis
7. Further exploration of land use parameters and expectations of developers applied to future works.

In addition to the general statements above, Figure 7 highlights a number of geometric configurations that should be confirmed, including connectivity and pipe sizing, as these may have a significant effect on the assignment of catchments and model performance.

3.5. Field Reconnaissance

Field observations are also an important aspect of validating predicted performance and issues. In combination with field survey, a general field reconnaissance is recommended to assess the following:

1. Channel stability, erosion and vegetation presence in targeted watercourses
2. Inlet and outlet conditions of culverts and storm sewers to observe signs of erosion, surcharging, and for the assignment of junction loss coefficients in future modeling
3. Exploration of manholes to better understand benching conditions and assignment of junction loss coefficients in future modeling.

3.6. CCTV Inspections and Flushing

We do not currently have an inventory of recently completed CCTV or other condition assessments, as such, our recommendation at this time is an allowance.

It is generally recommended that CCTV inspections be conducted on a 10-year cycle. Only CCTV reports less than 10 years of age should be counted on.

From Table 3.1 above, 10,000 lineal meters of trunk piping is of an age or material type that is of particular interest (metal, AC, wood, unknown). A planning level unit rate for CCTV inspection, scoring, and an allowance for flushing is $6 per meter, for a total cost of $60,000. It is likely that traffic control and other access challenges might arise, so we suggest an additional $20,000. However, there is no standard rate for this as each site needs to be evaluated on its own requirements.

This extent of work would likely take one year to complete assuming you can find a company that has the capacity. For planning purposes, it might be best to consider spanning this over 2 years (2019 – 2020).

4. Summary and Conclusions

This is a first of many steps in the City building a defensible, pragmatic and affordable long-range capital program for its drainage infrastructure.

The updated SDS Bylaw design storm criteria are a significant step forward in design requirements, resulting in greater runoff rates than would have been applied using past criteria. Courtenay is like all other communities working to address the projected impacts of climate change, and the City is encouraged to not be alarmed by the initial findings as this is the first of many steps in assessing the system and building a strategic plan. There will now be a need to evaluate the implications of this new data and help build a strategic plan that includes a review of level of service and risk of failure. The strategy will also be enhanced with new information gathering, monitoring and model calibration over time as discussed in Section 3.

This phase 1 hydraulic model is an important ingredient to the process, but in itself is insufficient to provide conclusive recommendations. Through this study, four priority systems have been identified that are most likely to result in capital improvements based on the combination of hydraulic performance and anticipated infrastructure condition. We have formulated a thoughtful preliminary 5 year program as summarized in Table 4.1 below. Specific locations of most activities are to be determined through further considerations.

Table 4.1 - Summary Capital Program (2019 -2023)

Year	Action	Estimated Cost
2019	Design and Construction	$1,500,000
	Monitoring	$72,000
	Data Gaps	$100,000
	Field Reconnaissance	$20,000
	CCTV	$40,000
	Model Calibration and Revised Capital Program (Phase 2)	$100,000
	Annual Total	$1,832,000
2020	Design and Construction	$1,500,000
	Monitoring	$30,000
	CCTV	$40,000
	Expand Assessment to Local Systems	$200,000
2021 through 2023	Design and Construction	$2,000,000
	Monitoring	$30,000

APPENDIX A
MODELLING SCOPE MEMO

MEMORANDUM

Date:	August 3, 2018
To:	Ryan O'Grady, Craig Perry
cc:	Rod Armstrong, Ehren Lee, Glen Shkurhan
From:	Tim Lutic
File:	3222.0044.01
Subject:	Courtenay Storm System Modelling Requirements

In conjunction with the City of Courtenay *trunks only* storm system modelling exercise being conducted by GeoAdvice, we are providing an outline of the expected tasks along with a draft watershed and trunk main map for reference. The goal is to provide the City with an overview of how the model is being set up and summarize key assumptions and data completeness.

The following objectives are identified for the trunk modelling exercise:

- Improve infrastructure base information for modelling purposes including understanding gaps for a trunks only model but other insights on data gaps for future, expanded modelling assignments
- Assess existing capacity of trunk conveyance system – GeoAdvice will summarize the modelled vs design flows in each pipe, as well as HGL levels, and assign a ranking to each based on flood risk
- Incorporate growth areas indicated in City of Courtenay OCP and in concert with the growth projections for the sanitary sewer and water master plans, plus the zoning projections from the Master Transportation Plan
- Assist with capital planning by summarizing stormwater deficiencies throughout the city

Through a review of the City of Courtenay stormwater GIS mapping, it is clear that significant data gaps exist throughout the stormwater system. The following table outlines several model input data requirements and associated data completion info.

Data	Responsibility	Estimated Data Completeness and Collection Requirements
Model Extents	Urban/City	100%, trunks only
Pipe Size	City	100%, included in GIS mapping
Pipe Lengths	City	100%, based on manhole locations
Pipe Material	City	100%, included in GIS mapping
Pipe Condition	City	80%, condition ratings included in GIS mapping
Pipe and MH Inverts	Urban	80%, picked up by City
MH Rims	Urban	80%, estimated based on LiDAR
Culvert Locations and Sizes	Urban	100%, included in GIS mapping
Detention Facilities	City	39 ponds mapped in GIS, 22 are privately owned (location only)
Control Structures	City	5 control structures mapped in GIS (location only)
Catchment Sizes	Urban	100%, from Lidar and City GIS mapping
Average Catchment Slope	GeoAdvice	100%, based on catchment boundaries and contour data
Imperviousness	Urban/GeoAdvice	100%, based on land use
Infiltration Rates	Urban	20%, assumed based on limited geotechnical information
Rainfall Data	Urban	100%, based on latest bylaws, including climate change
Land Use/Zoning	Urban/City	100%, existing based on GIS maps, future based on available growth maps and discussions

The modelling will be conducted under the following assumptions and clarifications:

- Trunk system is assumed to include storm mains larger than 600mm as well as all overland drainage pathways to open water (ocean or river), including culvert crossings.
- Model will consider existing conditions and future land use scenario. Imperviousness parameters based on land use types will be provided by Urban, as well as shapefiles of existing imperviousness. Future zoning shapefiles will be provided by Urban.
- Multiple rainfall events will be tested, including 2 year, 10 year and 100 year design storms of durations from 1 hour to 24 hours.
- Incorporation of climate change is expected, accounted for by scaling design events by 15%.
- Three months of rainfall and flow monitoring data is available for local model calibration in the Lerwick Road/Veteran's Memorial Parkway area.
- No additional survey or monitoring is anticipated for this phase of modelling. Missing inverts have been obtained by the City through CCTV and field measurements. Additional missing inverts will be assumed based on locally measured depths.
- Control structures, detention ponds and any other structures will not be included. Model will deal with conveyance only.
- Downtown subcatchments which do not have large trunk mains will be excluded from this iteration of modelling.
- All assumptions made during modelling will be documented. These can then be addressed in subsequent phases of modelling and analysis.

The attached map provides watershed delineation throughout the city and provides clear indication of the trunk modelling scope. Note the following key items:

- City watersheds labelled in yellow. GeoAdvice will create smaller sub-catchment boundaries within these to delineate trunk inlet contributions and land use variation.
- Proposed trunk conveyance system of pipes, channels and culverts to be modelled at this time are outlined in red.
- Outfalls which are to be included in trunk model are indicated.

Action items and next steps

GeoAdvice has committed to having a completed trunks only model by August 31, 2018. From this analysis, we will review the results and identify deficiencies and key locations for rainfall and flow monitoring over the winter of 2018/2019 (October-February).

Sincerely,

URBAN SYSTEMS LTD.

Tim Lutic, P.Eng.

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