URBAN STORMWATER RUNOFF QUALITY – LIFECYCLE ASSESSMENT

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ABSTRACT

Urban catchments are exposed to a wide range of pollutants from various sources, which are commonly described as diffused or non-point source pollution(NPSP). This paper is about a geo-spatial methodology applied to assess contaminant loads and analyse best practical options using the whole life cycle costs assessment. The geospatial / lifecycle approach leads the NPSP modeling towards advanced and optimised decision making that is necessary in determining and responding to the complex environmental issues.

NPSP is a significant contributor to water quality degradation in urban environments and poses a great challenge for control and abatement.

A sustainable approach to Catchment Management needs to incorporate NPS Load Modeling in order to understand impacts of urbanisation and other activities on the environment and in this particular case on stormwater runoff.

However, this area deserves more clarity within the industry and there are a number of challenges such as:

- The need for a consistent approach to analysis, tools and the data to be used in assessments;
- The need for clarity in interpretation, presentation and understanding of the outputs;
- The need for better communication of the appropriate information to various users and stakeholders.

The geospatial approach combined with lifecycle costs assessment enables the collection, analysis and modelling of relevant data with an advantage of combining existing and acquired geospatial data onto a single platform, thus enhancing strategic decision making for integrated and sustainable urban catchment management.

KEY WORDS:

Non point source (NPS) of pollution, contaminant load model, catchment management, spatial data, geospatial approach

1. INTRODUCTION

This paper describes Non Point Sources of Pollution (NPSP) assessment approach using the geospatial analysis model developed in ArcGIS software that also incorporates a lifecycle cost assessment in determining an optimisied response. The NPSP model has been applied to the New Lynn catchment as a pilot case study. The assessment is based on the spatial and non-spatial data analysis using Council records and the Stormwater Contaminant Load Model (CLM) guidelines developed by Auckland Regional Council (ARC).

Urban NPSP represents a significant contributor to water quality degradation. Catchment managers addressing non-point source pollution are increasingly in need of effective catchment management strategies and planning studies to evaluate the impact of existing and future development on water quality. A contaminant load analysis is an integral part of any Integrated Catchment Management Study. Geospatial information, analysis and models offer the advantage of combining existing and acquired geo spatial data onto a single platform thus enabling strategic decision making about the sustainable and integrated catchment management.

The main objective of this study is to apply a geospatial method for the calculation of NPS pollution utilising a yield rates for various pollutants as published by the Auckland regional Council, carry out load calculation and reduction analysis using lifecycle costs assessment to optimise responses.

The proposed geospatial methodology ultimately enables practitioners to achieve costs and timesavings and achieve optimised outcomes, thus making process itself more efficient and sustainable. In return the approach enables a very high level of compliance with the regulatory requirements to be achieved.

In applying this approach, the practitioners are required to standardize and moderate inputs from the existing geospatial data for inclusion into the NPS model. The NPSP model provides results in a form of database that contains relevant attributes for land use types, contaminant loading rates, source types and impervious area attributes. Overall NPSP geospatial modeling approach provides a greater flexibility and overview of the analysis process and adds immense capability for mapping and visualization of relevant parameters their trends and mitigation options.

2. BACKGROUND

NPSP represents a significant contributor to water quality degradation, which represents a unique challenge for control and abatement. It originates from wide areas, and the pollutant transport is highly variable.

A contaminant load analysis is an integral part of any Integrated Catchment Management Study (ICMS) and it is also part of the Auckland Regional Council (ARC) standard requirements. ICMS needs to demonstrate an understanding of contaminant loads from diffused sources typically correlated with urban land use types where quantum of impervious area plays a key role. In practice this requirement has met a variety of challenges such us a consistent approach to analysis, tools and data to be used in analysis and interpretation, including a clear understanding of the outputs by various users and stakeholders.

A previous works by others include a combined study with findings of three separate projects in Auckland was commissioned by ARC in 2005. This study provided most of the data required to enable metal sources in urban catchments of different land use to be identified and quantified (Timperley et al, 2005).

At the time, a contaminant load model, in an excel spreadsheet format, has been developed based on this study with aim to simplify the computation of sediment, zinc, copper and petroleum hydrocarbons loads within a given land area. This model brought together the best data available at the time for contaminant yields and the efficiencies of various management options for reducing the amounts of contaminants leaving a site (Timperley, 2006).

Further work on integration of various models into regional harbour sediment / contaminant accumulation model (USC- 3) was published in the following papers:

1. "Stormwater Contaminant and Sediment Load Modelling in the Central Waitemeta and South-eastern Manukau Harbour Catchments" (Timpereley et al , 2009);

2. "Overview of Predicting Long Term Contaminant Runoff and Accumulation in the Central Waitemata and Southestern Manukau Harbours" (Johnatan Moores and others 2009);

3. Distribution of Metal and Sediment accumulation in the Central Waitemata and Manukau Harbours" (Jacquie Reed et al, 2009).

A relationship of CLM and the Waitemaata Harbour model that is an ongoing programme run by ARC has been explored. Several technical papers were published at the Stormwater Conference in Auckland in 2009. With respect to the harbour modelling, "Outputs from CLM are used as inputs into a regional harbour sediment / contaminant accumulation model (USC- 3)" (Timperley at al 2009).

Based on the previously published technical papers it was concluded that the geospatial approach including lifecycle costs assessment would provide numerous advantages over a CLM spreadsheet modeling previously used and also enable a greater compatibility with the ARC requirements.

Data inputs for the CLM spreadsheet model include the total site area of various contaminant source types (different land use types), the length of each category of roads, the contaminant management options for each source and the fractions of the source and sites areas draining to the management option trains. To be able to obtain these data inputs, it is necessary to derive data from a geospatial information database. In order to present the outputs in a map format it is also necessary to export the results into the spatial GIS database. This "double handling" is considered unnecessary as using the appropriate tools in the ArcGIS the NPSP model can be used not only to produce data necessary for input to perform CLM analysis but also to calculate contaminant loadings and reductions and present them visually.

Data from the Council's spatial database can be structured and classified through ArcGIS in various data layers such as: soils, land use, surface water, elevations, watershed boundaries, political boundaries, and locations of built-up structures, roads, point sources and so on. It enables the creation of additional data layers that can be created or derived from the base data layers. These may include cell slope, slope length, length-slope factor, water quality index and erosion index. Spatial data sets can also be used in combination with existing hydrological models or on its own in assessment of nonpoint source pollution (Krpo, 2007).

The geospatial analysis approach used in the NPSP model and applied to the New Lynn study area provides means of storing, manipulating and displaying the remarkable volumes of spatial and non spatial data.

A further enhancement of the NPSP modeling has been achieved by adding a lifecycle costs assessment to analyse options for management and mitigation of the pollutants. It is considered that a spatial approach provides the best framework for assessment of contaminant loads based on the regulatory guidelines and requirements. Almost all data required for the contaminant load analysis exists in Council's electronic data systems.

3. STUDY SCOPE AND EXTENT

The study scope was to develop the Geospatial NPS model prepare, analyse, compute and present information using ArcGIS. For this purpose the study area was chosen at New Lynn as shown in Figure 1.

Figure 1: Study Area

4. METHODOLOGY

Understanding the different types of data and assessing the quality / capability of data is a key aspect of the spatial approach. The quality of the data inputs will have a direct impact on the resulting outputs. Hence before analysis is preformed, an audit of the data should be undertaken to ensure that the right data and formats are being used.

NPSP within the study area is represented through different land use types. Table 1 shows land use types (source types) applied in this study as per ARC guidelines.

The Spatial Analysis method developed for this project can be divided into three parts:

a. The database development of:

- Contaminant yields for various source types based on current and future land coverage;
- Reductions efficiencies values for various treatment options applied on different source types;
- Input and output datasets.

b. The development of model/tools to select the specific source type (based on land cover), classification of selected source types based on various criteria e.g. slope, roof material type, number of vehicles per day on roads, data joining of contaminant yields and different source (land cover) classes, calculation of contaminant source area and calculation of initial contaminant load.

c. Calculation of reduced load based on load reduction efficiency values, initial contaminant load and contaminant source area.

NPS of Pollution
Roofs
Roads
Paved Surfaces other than roads
Urban Grass Lands
Urban Stream Channel
Construction Site (2) open for 6 months/year
Construction Site (3) open for 12 months/year
Stable bush

Table 1: Source Types

4.1 NON-SPATIAL DATA MANAGEMENT

4.1.1 CONTAMINANT YIELD RATES

Contaminant yield rates are available from the ARC CLM spreadsheet. Hence the database with contaminant yields for various source types including reduction factors for different management options was developed and stored in the ArcGIS geodatabase. The geodatabase is the common data storage and management framework for ArcGIS. It supports all the different types of data that can be used by ArcGIS such as attribute tables, geographic features, satellite and aerial imagery, surface data and survey results.

The geodatabase offers the ability to store a rich collection of data types in a centralized location, apply sophisticated rules and relationships to the data, maintain integrity of spatial data and integrate spatial data with other IT databases (Perencsik et al., 2005).

Figure 2 shows the example of contaminant yields and reduction efficiencies Geodatabase.

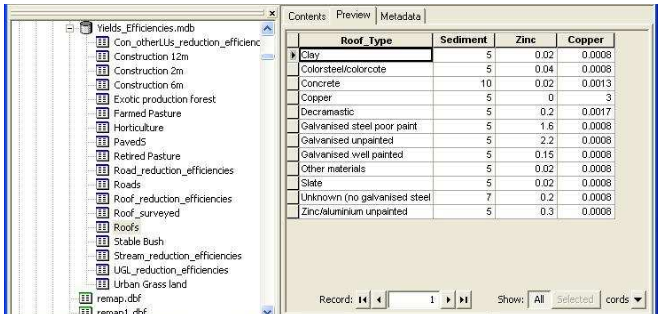

Figure 2:Yields and Reduction Efficiencies Geodatabase

Contaminant yield rates and reduction efficiencies represent non-spatial dataset and it means that it needs to be linked to spatial features to be useable in the analysis. Thus, the geodatabase with the yield rates and reduction efficiencies has been linked to the study area source types enabling computation with relevant factors within each source type area.

4.1.2 TRAFFIC COUNTS

The other non-spatial dataset needed for this model is Average Daily Traffic (ADT) counts. This data was obtained from the Council and joined to the road shapefile, which is a spatial dataset. ArcGIS contains the tools to join tabular data with geographic features and displays the data on the map. Joining data in this case was used to append the fields of traffic counts table to those of 'road' geographic feature through an attribute or field common to both datasets – road names. A number of minor roads lack ADT data and assumption was made ADT <1000 to be used for them.

4.2 SPATIAL DATA MANAGEMENT

Raster and vector spatial data sets are used in this study to illustrate the landscape and implement various geospatial analysis.

Vector model represents the world with points, lines and polygons. This model is specifically useful for representing features such as parcels, pipes, building footprints, water outlet points and similar. ArcGIS stores vector data as features in feature classes and collection of feature classes.

Raster model represents the world as a surface divided into a regular grid of cells. This model is useful for representing the data that varies continuously. Aerial images, digital elevation models, slope surfaces are examples of geographic information in raster format.

Vector data layers can be converted into raster data layers and vice versa relying on the conventions that a point may be represented as a single grid cell, a line may be represented as a string of grid cells, and a polygon may be represented as a zone of cells. ArcGIS contains the tools for format conversion working on raster and vector data sets.

Table 2 summarises the base spatial data needed for this model, its availability and source.

Table 2: Spatial data

Spatial data feature / File Name	Comment
Contour	The slope analysis is based on the Lidar data contours.
Impervious Area	The impervious area within the catchment is provided in various layers as roads, roofs and other.
Stormwater Line	Stormwater lines data set contains valuable attributes that are used to aid the data preparation; however they are not part of NPS assessment.
Stormwater Point	Stormwater point's data set contains valuable attributes that were used to aid the data preparation; however they are not part of the NPS assessment.
Parcel Boundary	Parcel boundaries with their attributes are provided from Council's Spatial database.

District Plan Zone	District plan zone layer is sourced from the Council's spatial database. This data has been reclassified to suit land cover classes suitable for NPS analysis.
Road Network	Road network layer is sourced form the Council's Spatial database.
Stream/River	Stream River layer are sourced from Council's Spatial database. The land cover (source type) is determined by calculating a typical width of the stream at critical locations.
Building Footprints	Building footprints source from the Council's Spatial database. This dataset was updated with roof material values.
Stormwater Treatment Devices	Locations for the existing stormwater treatment devices were provided. The catchments were determined by observation of the stormwater networks, their discharge points and land contours.
Construction Sites	Railway corridor and the site at the Corner of Astley Ave / Margan Rd were identified as construction site.
Aerial Images	Aerial images are sourced from Council's Spatial database. Used for helping determining the land cover (source type).

4.3 SPATIAL MODEL INPUT DATA PREPARATION

Table 3 represents datasets created and/or refined to be valid model inputs.

Table 3: Created Datasets

Created Spatial data feature/File Name	Description
Roof	Building Footprints file updated with roof material type attributes
Road	Road network file updated with traffic counts attributes. The layer comprises a number of polylines from which the areas are calculated based on length and code area as per ARC guidelines.
Paved Surfaces other than roads	Impervious Area file updated by erasing roads areas and intersected with District Plan file to assign residential, commercial and industrial LU values
Source Type dataset/codes: Urban Grass Lands Stable Bush Urban Stream Road Residential Industrial Commercial Construction site – 6 months Construction site – 12 months	District Plan Zone file updated with Source Type Codes
Stormwater Treatment Catchments	Newly created file representing stormwater treatment catchment areas
DEM	Digital elevation model Developed from LIDAR contour data
Slope	Surface slope file derived from digital elevation model and reclassified (i.e. <10; 10-20; 20< degrees)

4.4 SPATIAL ANALYSIS OF INITIAL CONTAMINANT LOAD

A separate tool is developed for each contaminant source as there is a mixture of various parameters required to evaluate contaminant loads for diverse land use types.

By clicking on the tool e.g. ‘Road’, dialog box appears for user to choose input and output file. Initial contaminant load is calculated and new road file created with contaminant loads attributes for each segment of the road.

4.5 SPATIAL ANALYSIS OF REDUCED LOAD

Reduced contaminant loads are evaluated based on load reduction efficiency values, initial contaminant load and fraction of contaminant source area (as per ARC guidelines).

5. RESULTS

The analysis included options as follows:

Option 1 Contaminant loads calculated for the current NPS source types

Option 2 Contaminant loads calculated changing NPS source type for the site at the Corner of Astley Ave / Margan Rd to a construction site open for 12 months

Option 3 Contaminant loads calculated assuming the site at the Corner of Astley Ave / Margan Rd is a fully developed residential site (with assumed 65 % imperviousness – 50 % building and 15 % paved surfaces)

A summary of results for each option is presented in Table 4.

The key outputs from the assessment are presented as follows:

- Spatial database that contains required inputs for NPSP modeling including land use, contaminant yield values, reduction efficiency values, impervious areas, roads etc. This database can be used interactively for further analysis of preferences for stormwater treatment options.
- The same database contains calculated contaminant loads for Options 1 to 3
- Contaminant yields and reduction factors database
- Maps visualising modeling results per each NPS type area and normalised loads for each source expressed in kg/area/ annum (e.g. Option 2 Sediment loads as shown in Figure 5)
- Summary of the NPS loadings in table format for Options 1 to 3
- Table with costs estimates for treatment provisions per NPS contaminant
- Kml (GoogleEarth file format) files representing CLM results

Figure 5: Option 2 – Initial and Reduced Sediment Loads

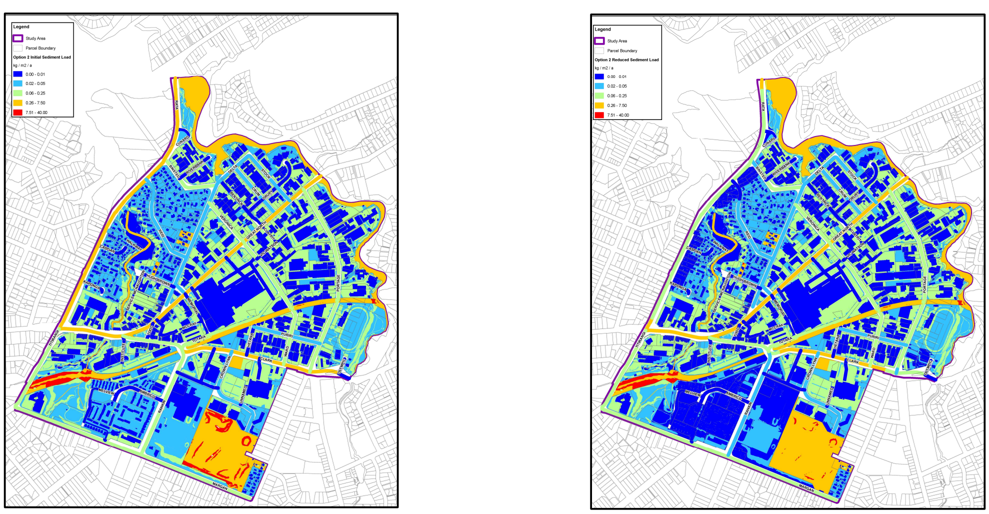

Table 4: Summary of the NPS loadings Options 1 to 3

Option 1 - Current Status														
Source Type	Area	Area Variance Vs Option 1	Sediment Initial	Sediment Reduced	Sediment Variance	Zinc Initial	Zinc Reduced	Zink Variance	Copper Initial	Copper Reduced	Copper Variance	TPH Initial	TPH Reduced	TPH Variance
	m2	m3	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum
Road	263,677	-	33,360	26,094	7,266	120	104	16	39	32	7	598	531	68
Roofs	364,303	-	1,890	1,701	189	241	238	2	0	0	0	-	-	-
Paved Surfaces Commercial	290,206	-	29,021	27,871	1,150	15	14	0	15	14	0	-	-	-
Paved Surfaces Industrial	16,876	-	844	194	650	2	0.8	1	2	1	2	-	-	-
Paved Surfaces Residential	39,290	-	786	506	280	3	2.1	1	0	0	0	-	-	-
Urban Grass lands	376,234	-	16,270	11,321	4,949	-	-	-	-	-		-	-	-
Urban Stream Channel	54,116	-	324,698	324,698	-	-	-	-	-	-		-	-	-
Construction Site 6 months	6,025	-	8,122	8,122	-	-	-	-	-	-		-	-	-
Construction Site 12 months	32,343	-	278,181	271,099	7,083	-	-	-	-	-		-	-	-
Stable Bush	29,838	-	1,114	1,114	-	-	-	-	-	-		-	-	-
SUM	1,472,907	-	694,285	672,718	21,567	379	359	20	56	48	9	598	531	68

Option 2 - Future 1														
Source Type	Area	Area Variance Vs Option 1	Sediment Initial	Sediment Reduced	Sediment Variance	Zinc Initial	Zinc Reduced	Zink Variance	Copper Initial	Copper Reduced	Copper Variance	TPH Initial	TPH Reduced	TPH Variance
	m2	m3	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum
Road	263,677	-	33,360	26,094	7,266	120	104	16	39	32	7	598	531	68
Roofs	364,303	-	1,890	1,701	189	241	238	2	0	0	0	-	-	-
Paved Surfaces Commercial	290,206	-	29,021	27,871	1,150	15	14	0	15	14	0	-	-	-
Paved Surfaces Industrial	16,876	-	844	194	650	2	1	1	2	1	2	-	-	-
Paved Surfaces Residential	39,290	-	786	506	280	3	2	1	0	0	0	-	-	-
Urban Grass lands	309,344	- 66,890	13,335	10,634	2,701	-	-	-	-	-	-	-	-	-
Urban Stream Channel	54,116	-	324,698	324,698	-	-	-	-	-	-	-	-	-	-
Construction Site 6 months	6,025	-	8,122	8,122	-	-	-	-	-	-	-	-	-	-
Construction Site 12 months	99,233	66,890	614,040	349,190	264,850	-	-	-	-	-	-	-	-	-
Stable Bush	29,838	-	1,114	1,114	-	-	-	-	-	-	-	-	-	-
SUM	1,472,907	-	1,027,209	750,123	277,086	379	359	20	56	48	9	598	531	68
Variance Option 1 (O2-O1)	-	-	332,924	77,405	255,519	-	-	-	-	-	-	-	-	-

Option 3 - Future 2														
Source Type	Area	Area Variance Vs Option 1	Sediment Initial	Sediment Reduced	Sediment Variance	Zinc Initial	Zinc Reduced	Zink Variance	Copper Initial	Copper Reduced	Copper Variance	TPH Initial	TPH Reduced	TPH Variance
	m2	m3	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum	kg/annum
Road	263,677	-	33,360	26,094	7,266	120	104	16	39	32	7	598	531	68
Roofs	397,793	33,490	2,058	1,701	357	246	243	3	0	0	0	-	-	-
Paved Surfaces Commercial	290,206	-	29,021	27,871	1,150	15	14	0	15	14	0	-	-	-
Paved Surfaces Industrial	16,876	-	844	194	650	2	1	1	2	1	2	-	-	-
Paved Surfaces Residential	49,352	10,063	987	552	435	3	3	1	0	0	0	-	-	-
Urban Grass lands	332,681	- 43,553	14,395	10,890	3,506	-	-	-	-	-	-	-	-	-
Urban Stream Channel	54,116	-	324,698	324,698	-	-	-	-	-	-	-	-	-	-
Construction Site 6 months	6,025	-	8,122	8,122	-	-	-	-	-	-	-	-	-	-
Construction Site 12 months	32,343	-	278,181	271,099	7,083	-	-	-	-	-	-	-	-	-
Stable Bush	29,838	-	1,114	1,114	-	-	-	-	-	-	-	-	-	-
SUM	1,472,907	-	692,779	672,333	20,446	385	364	21	56	48	9	598	531	68
Variance Option 1 (O3-O1)	-	-	- 1,506	- 385	- 1,121	6	5	1	-	-	-	-	-	-

6. CONCLUSIONS

6.1 GEOSPATIAL APPROACH

The Geospatial Approach (NPSP model) developed for assessment of contaminant loads in stormwater runoff is a useable, reliable and repeatable means of estimating NPS pollutant amounts in stormwater runoff. The principal benefit of NPS geospatial approach to environmental modeling is to enable processing large volumes of data that geographically anchor many environmental processes (Corwin, 2006).

Good qualities of spatial datasets are readily available from Council's GIS database. Spatial analysis and models offer the advantage over the existing simplified spreadsheet approach. Geospatial approach combines existing and acquired geo spatial and non-spatial data onto a single platform thus enabling strategic decision making about the integrated and sustanble catchment management.

Preparation of the input data is critical for the successful modeling. The key issue is about consistency and quality of the available data sets. In some cases significant data acquisition and preparation effort may be required. Practicality is also an issue and an optimised approach in terms of accuracy and costs should be considered.

As an example, in this study, determining the roof type was one of the most challenging parts for data preparation. The roof types were determined on a basis of visual inspection by close observation on site or using binoculars where a direct access was unavailable. Inspection was carried out for about 40% of the roofs within the study area. The findings were then extrapolated to the roofs that have not been inspected. For estimation we have also used aerial imagery and year of the construction of particular property. For the purpose of this scope it is considered that this approach is practical in terms of costs vs accuracy. However in other cases where the goal would be to achieve greater certainty (e.g. for legal or rating objectives) regular inspections involving access onto the roofs and good record keeping process would be required to provide more accurate and reliable information.

A map showing roof materials is represented in Figure 6.

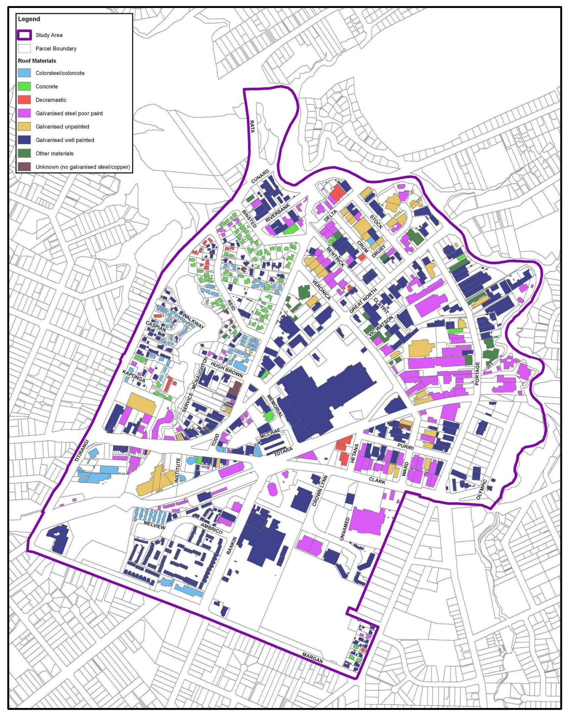

Figure 6: Roof Materials

6.2 OUTPUTS

The following discussion is focused on some of the key outputs leading to a lifecycle costs assessment modeling.

The total study area is 147 ha. The total suspended solids load for Option 1 is 694 tonnes where most of the load comes from the urban stream channels (48 %) and construction sites (40 %). The results are biased towards those source types because the CLM rates appear to be highest for that group. Refer to Figure 7 below.

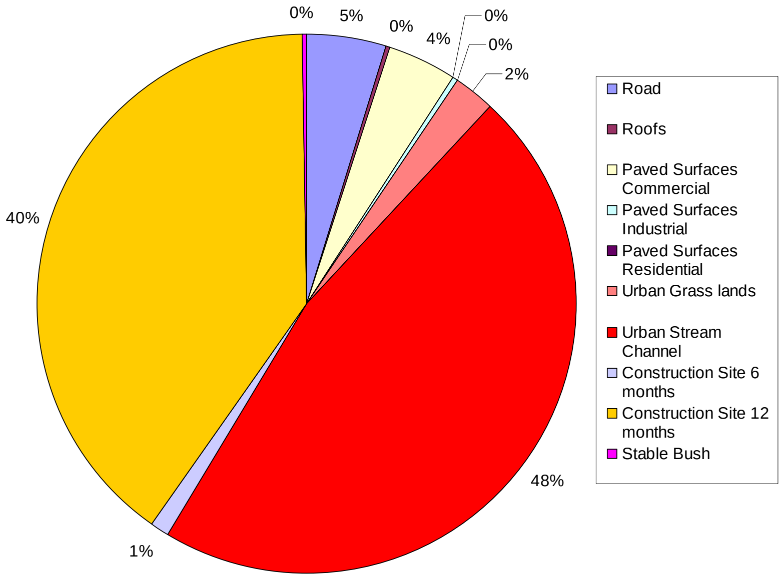

Figure 7: Suspended Solids Loadings Option 1

Sensitivity of the changes of source type inputs (land use changes) has been tested through option 1 to 3 and also factoring in the reduction rates achieved by the existing treatment devices. A summary of the loadings (Table 4) suggests that the most significant changes are related to the suspended solids. This is because the difference in the published CLM loadings is significant. On other side there were no significant changes noted with heavy metals.

Normalised the outputs are derived by yield rate assigned back to each discrete area defined by a polygon of a particular source type. This gives in return, ability to visualise where the pollution is coming from and to prioritise a treatment response on a geospatial basis.

The outputs can be used as an aid to choose the future treatment locations and costs estimates and an area wide basis. Current treatment catchments and devices are shown in Figure 8. The currently serviced area is approximately 34 ha. The total treatable area is approximately 101 ha. This is calculated as total study area 147 ha deducted for bush, stream, urban grass area of 46 ha. Thus the remaining area to be treated is 67 ha multiplied with $ 70,000 /ha equals $ 4.7 million for implementing stormwater treatment within the study area. The rate is adopted from the New Lyn LID Feasibility Study 2009.

A lifecycle cost assessment has been used to optimise the NPSP management response in sustainable and integrated manner. A summary of results is shown in Figure 9 below.

As an illustration of a possible deception in determining the management options, the change of costs can be observed through the lifecycle steps where initially the wetland implementation costs are highest while the catch pit filter bag implementation costs are the lowest. However applying a whole life cycle analysis the filter bags come over a three times more costly than wetlands.

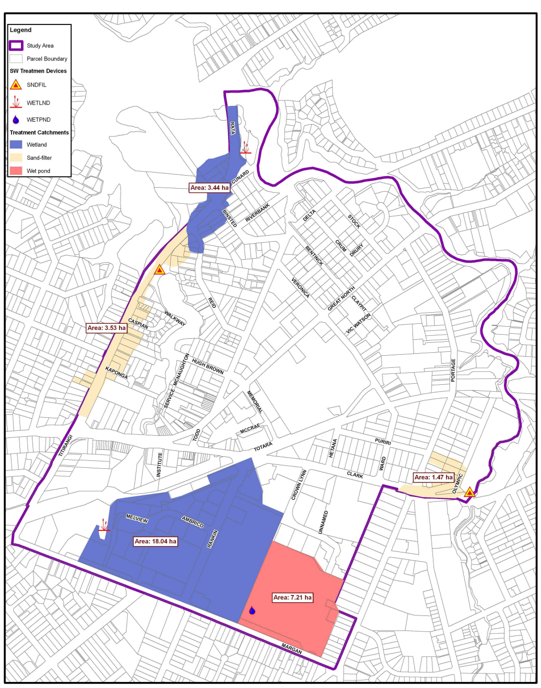

Figure 8: Current treatment catchments and devices

	Total Service Ctch Area	Currently Treated Ctch Area	Future Treated Ctch Imperv Area	Implementation Costs/ Area	Implementation Costs	Annual Maintnce Cost	Annual Deprec	SWQID Life Cycle	Asset Disposal Cost	Total Life Cycle Costs (LCC)	Total Annual LCC	Annual LCC per Area	Annual LCC per Tonne
Option 1	ha	ha	ha	$/ha	$	20%	1%	Yrs	10%	$	$/yr	$/yr/ha	$/yr/t
Wetland Only	101	34	67	140,000	9,380,000	938,000	93,800	100	0	10,411,800	104,118	1,554	1,827
				Costs/ha	140,000	14,000	1,400		0	155,400	1,554		

Option 2	ha	ha	ha	$/ha	$	0	0	50	0			$/yr/ha	$/yr/t
SWQID (Smal Wetland, Bioretetion, Prop Device,Swl) excl CPFB	101	34	67	70,000	4,690,000	938,000	93,800	50	469,000	6,190,800	123,816	1,848	2,172
				Costs/ha	70,000	14,000	1,400		7,000	92,400	1,848		

Figure 9 – Summary of lifecycle costs assessment for mitigation and management options

Option 3 A	No	No of CP within Treated Ctch Paved Area	No of CP Future Treated Ctch Paved Area	Implementation Costs/ CP	Implementation Costs	Annual Maintenance Cost	Annual Depreciation	FB Life Cycle (Yrs)	Asset Disposal Cost	Total Life Cycle Costs (LCC)	Total Annual LCC	Annual LCC per area	Annual LCC per Tonne
CP FB	no	no	no	$/CP	$	0	0	Yrs	0	$	$/yr	$/yr/ha	$/yr/t
CPSing	424	83	341	1,300	443,300	44,330	88,660	5	44,330	620,620	124,124		
CPDoub	27	7	20	2,600	52,000	5,200	10,400	5	5,200	72,800	14,560		
CPSup	3	0	3	3,900	11,700	1,170	2,340	5	1,170	16,380	3,276		
Total CP	454	90	364		507,000	50,700	101,400	5	50,700	709,800	141,960	4,895	5,754
cp/ha	7	3	13	Costs/ha	17,483	1,748	3,497		1,748	24,476	4,895		
Serviced Area	63	34	29										
			0										
Option 3 B													
Balance Area Treated by SWQID			38	70,000	2,660,000	938,000	93,800	50	519,700	4,211,500	84,230	2,217	2,605
				Costs/ha	70,000	24,684	2,468		7,757	110,829	2,217		
Option 4			67		3,167,000	988,700	195,200		570,400	4,921,300	226,190	3,376	2,976
CP FB + SWQID				Costs/ha	47,269	14,757	2,913		8,513	73,452	3,376		

Figure 9 – Summary of lifecycle costs assessment for mitigation and management options

So, this pilot study demonstrates that the geospatial approach provides insights into all phases of the assessment and supports decision-making process involved in preparing and optimising responses. The key aspects to consider in applying the spatial approach to NPS analysis are:

- Leveraging on systems and procedures that are already in existence in other activity areas of the Council and adjusting them where necessary for a specific purpose of NPS approach.
- Collaboration between key stakeholders, departments as well as individual practitioners.
- Building up organisational capabilities in spatial science and providing for innovation and learning.

In conclusion the geospatial approach combined with lifecycle costs principles provides a great tool for exploring and resolving complex relationships in environmental engineering and science. The NPSP modeling is an area where the proposed approach provides efficiency in analysis of effects, service demand, asset management, priorities and optimised decision making processes.

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