BIM TECHNOLOGIES FOR INTELLIGENT ROAD STORMWATER DESIGN: AUTODESK CIVIL 3D & DEVOTECH IDAS

By Shuaib Yunos, Senior BIM Technical Specialist
Baker Baynes

INTRODUCTION

Building information modeling (BIM) is an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to plan, design, construct and manage buildings and infrastructure. BIM technologies can be utilised for road stormwater networks by municipal engineers, civil engineers, consultants, and other design professionals to design and analyse stormwater networks in an intelligent and futuristic manner, promoting digital transformation and sustainable design, construction, and civil infrastructure delivery in South Africa and abroad. This paper provides a high-level overview of the application of Autodesk Civil 3D and Devotech iDAS for road stormwater networks, with a process overview presented by Shuaib Yunos at the 85th IMESA Conference in 2022.

CATCHMENTS

<u>Derivation of Catchments</u>

Typically, the derivation of catchments is done on Google Earth, with the designer drawing a polygon of the catchment(s) extents. Flow paths and then drawn, with the lengths and slopes recorded. This is a tedious task, with the following drawbacks:

- The data is static, meaning when changes occur, data needs to be manually updated or recorded again.
- The catchments & flow paths drawn are subjective to the interpretation of the designer.
- The catchments & flow paths need to be redrawn in a CAD platform, creating rework due to a data silo effect.

Using Autodesk Civil 3D, a watershed analysis can be executed, resulting in the derivation of catchment areas. This results in a computational output, which is not purely subjective to the designer, providing an automated and analytical output, with the watersheds derived for a site depicted below:

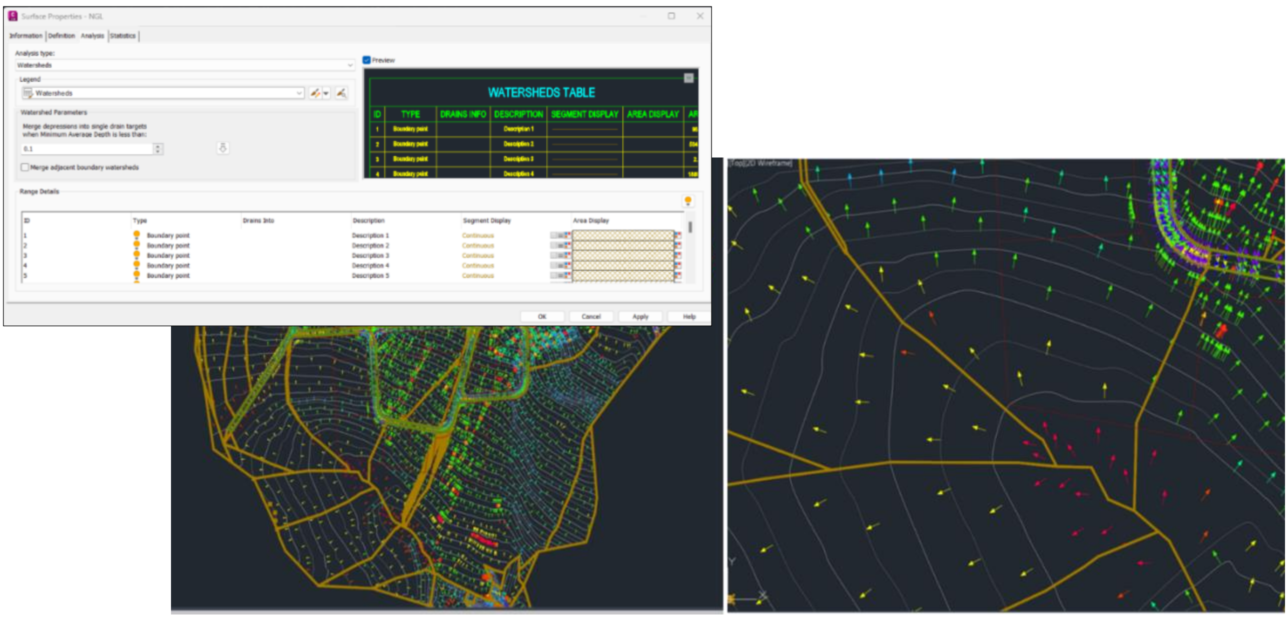


Figure 1: Watershed Analysis using Autodesk Civil 3D

MODELING OF STORMWATER

Using Polylines

With the low points established and catchments derived, the stormwater network can be drawn. The most common way used to achieve this is using polylines. It is good practice to draw the network in the direction of flow. To ensure no errors in analysis, vertices should be broken at crossing points. This is a tedious task to do manually, but with the advantage of BIM technologies, a map clean-up function is available in Autodesk Civil 3D to achieve this in an automated manner.

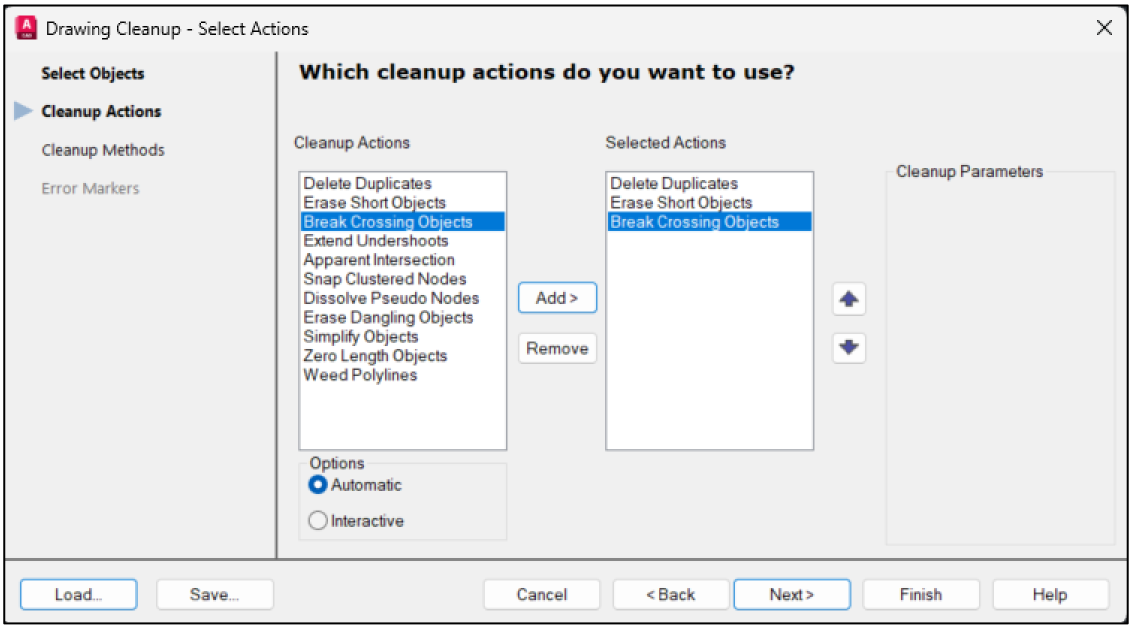


Figure 2: Map Clean-Up Function using Autodesk Civil 3D

Network from Polyline

With the polyline drawn representing the stormwater network, we can now use Devotech iDAS in Autodesk Civil 3D to convert the polyline to 3D stormwater network. Devotech iDAS is an add-on to Autodesk Civil 3D developed by the Devotech Group of Companies in South Africa. The add-on provides design automation for road and pipe network designs, with the advantage of localisation as per South African standards. When creating the network from polyline, the designer can select from a range of pipes and structures popularly used in South Africa.

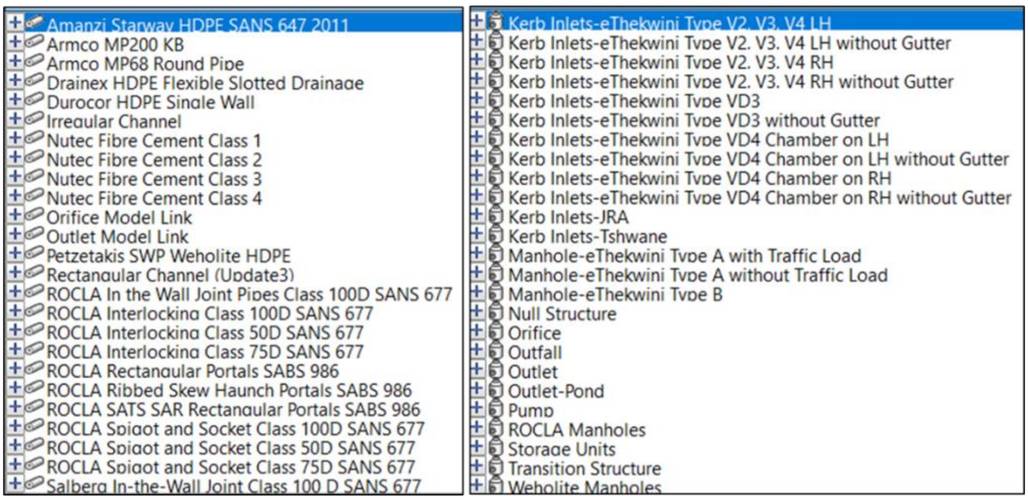


Figure 3: Example of Available South African Pipe & Structure Catalogues

Pipes and structures used can be swapped or changed if required after the generation of the network. The network in plan is now complete. Other functions such as regrading the network and flow direction are also available.

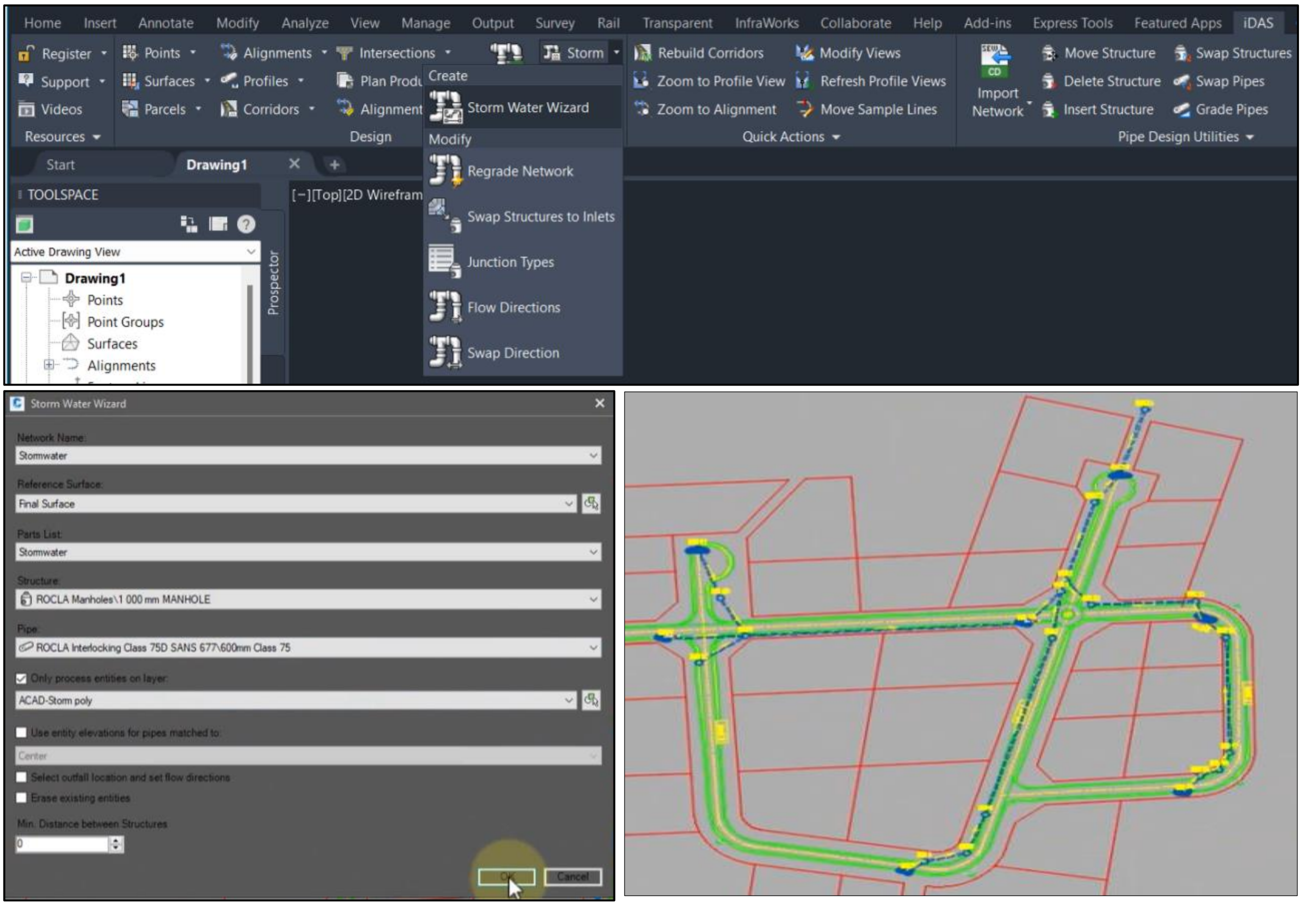


Figure 4: Stormwater Network Generated using Devotech iDAS in Autodesk Civil 3D

Creating Flow Paths

With the catchments computed, the designer can then identify the tributary areas and create flow paths to inlets and/or low points using the water drop function, which computes the flow path of water from the point of selection as portrayed below, with the cyan X symbol signifying the start of the flow path.

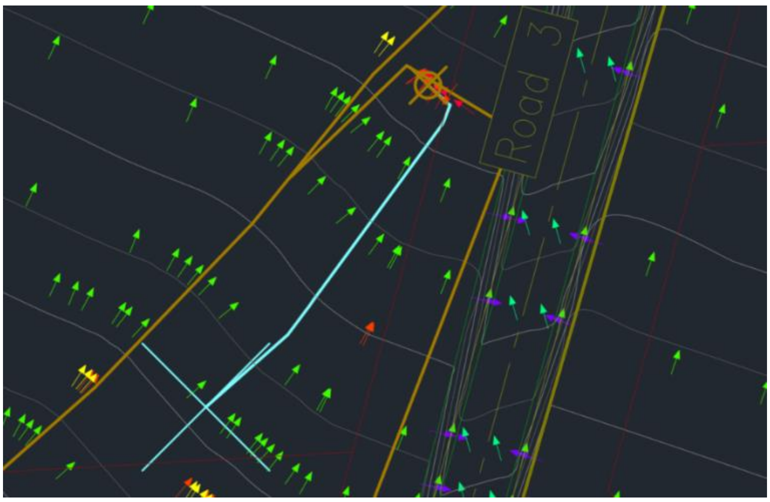


Figure 5: Flow Path Created using Water Drop Function in Autodesk Civil 3D

Generating Long Sections/Profile Views

With the network generated, pipe long sections/profile views can be created and modified accordingly using CAD grips or other functions available on the ribbon provided by Devotech iDAS. Long sections can be edited in the Devotech iDAS Pipe Manager or in Autodesk Civil 3D, based on user preference, with a preview of a long section from the iDAS Pipe Manager and Autodesk Civil 3D below:

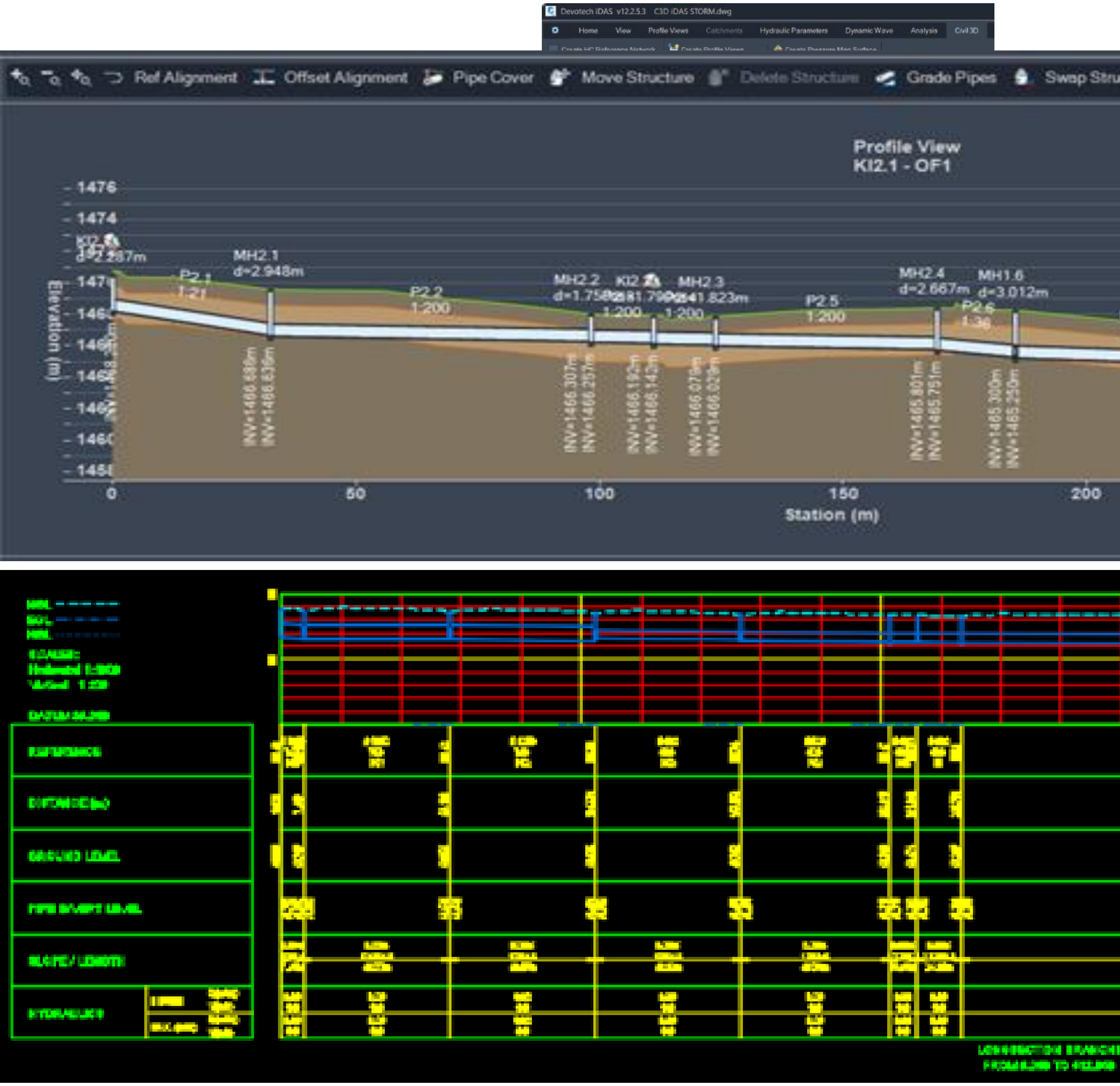


Figure 6: Long Section using Devotech iDAS in Autodesk Civil 3D

Swapping of Pipes & Structures

With long sections/profile views generated and output to Autodesk Civil 3D, designers can then swap pipes and structures in plan or profile view, by taking advantage of the functionality provided by Devotech iDAS. Other options such as deleting structures, grading pipes, and other functionality are also available.

Figure 7: Network Modification Functionality using Devotech iDAS in Autodesk Civil 3D

Regrading of Stormwater Network

When it comes to specific grades and depths, a branch or entire network can be regraded, to comply with the desired engineering inputs, using the regrading function provided by Devotech iDAS.

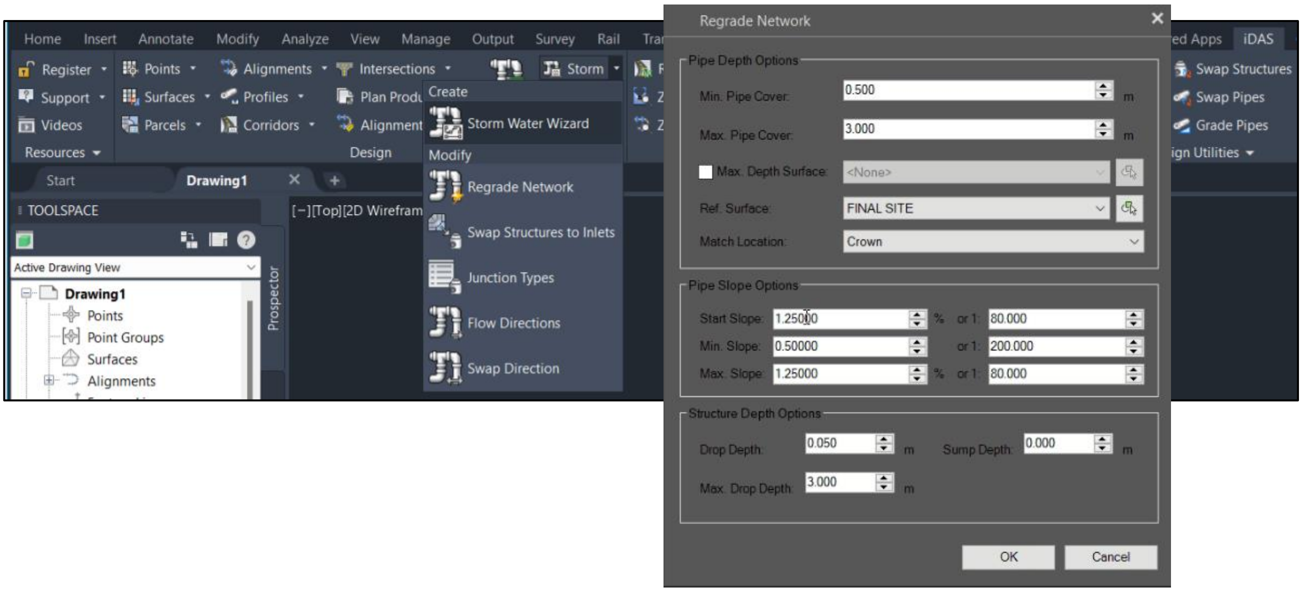


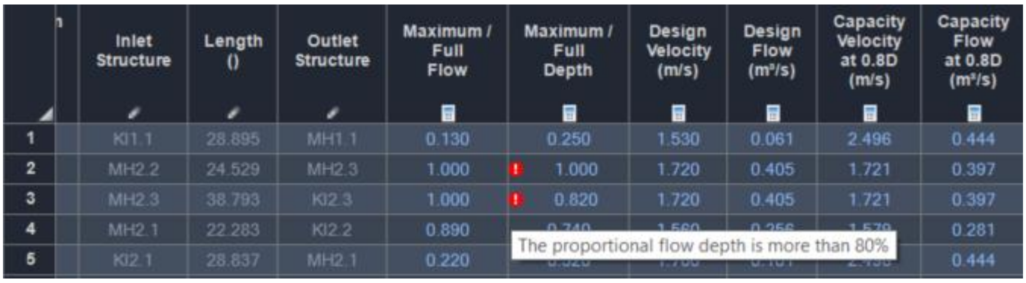
Figure 8: Regrading Functionality using Devotech iDAS in Autodesk Civil 3D

STORMWATER ANALYSIS

When designing a stormwater network, the network needs to consist of pipes and structures that are of optimal size to function efficiently. The sizing of the network is directly related to the expected surface runoff, i.e., the input analysis. With the combination of local and internationally developed software, the modeling and analysis can be achieved in the same interface, without the need to export/import across different software.

The runoff calculation methods available are that of Rational & EPA SWMM, with the option to specify analysis using steady flow, kinematic, or dynamic wave. With the Rational Method, the time of concentration (ToC) can be calculated using either Kirpich or Kerby formulae, with related analysis values derived from the SANRAL Drainage Manual and Intensity-Duration-Frequency (IDF) curves as per THE CIVIL ENGINEER in South Africa – March 1979. With regards to the EPA SWMM Method, the average catchment slope can be either specified or computed based on the start-end relative to the terrain, with equivalent width and rain gage also being able to be derived accordingly. This paper will provide a very high-level overview focusing on the Rational Method.

With the hydrology method set to Rational, the catchments and flow paths can then be selected individually or derived automatically. With the catchments, flow paths, runoff coefficients and inlet structures now specified, values such as flow path length, average slope, ToC, rainfall intensity, and runoff are computed per catchment. The Manning`s Roughness coefficient can also be set for conduits as dictated, including design velocity and maximum flow depth. Upon running an analysis of the network, the tabular information will flag items that are non-compliant as per the design criteria set. This provides an easier method to the municipal engineering professional to check the suitability of their design against the required specifications.



	Inlet Structure	Length ()	Outlet Structure	Maximum / Full Flow	Maximum / Full Depth	Design Velocity (m/s)	Design Flow (m³/s)	Capacity Velocity at 0.8D (m/s)	Capacity Flow at 0.8D (m³/s)
1	KI1.1	28.895	MH1.1	0.130	0.250	1.530	0.061	2.496	0.444
2	MH2.2	24.529	MH2.3	1.000	! 1.000	1.720	0.405	1.721	0.397
3	MH2.3	38.793	KI2.3	1.000	! 0.820	1.720	0.405	1.721	0.397
4	MH2.1	22.283	KI2.2	0.890	[illegible]	[illegible]	[illegible]	[illegible]	0.281
5	KI2.1	28.837	MH2.1	0.220	[illegible]	[illegible]	[illegible]	[illegible]	0.444

The proportional flow depth is more than 80%

Figure 9: Violation of Proportional Flow Depth Flagged using Devotech iDAS Pipe Manager

With this constant check of design versus specifications, the design professional can analyse the stormwater network under various design inputs and return periods to arrive at a best-suited solution, with options available on the top ribbon for ease of use as depicted below:

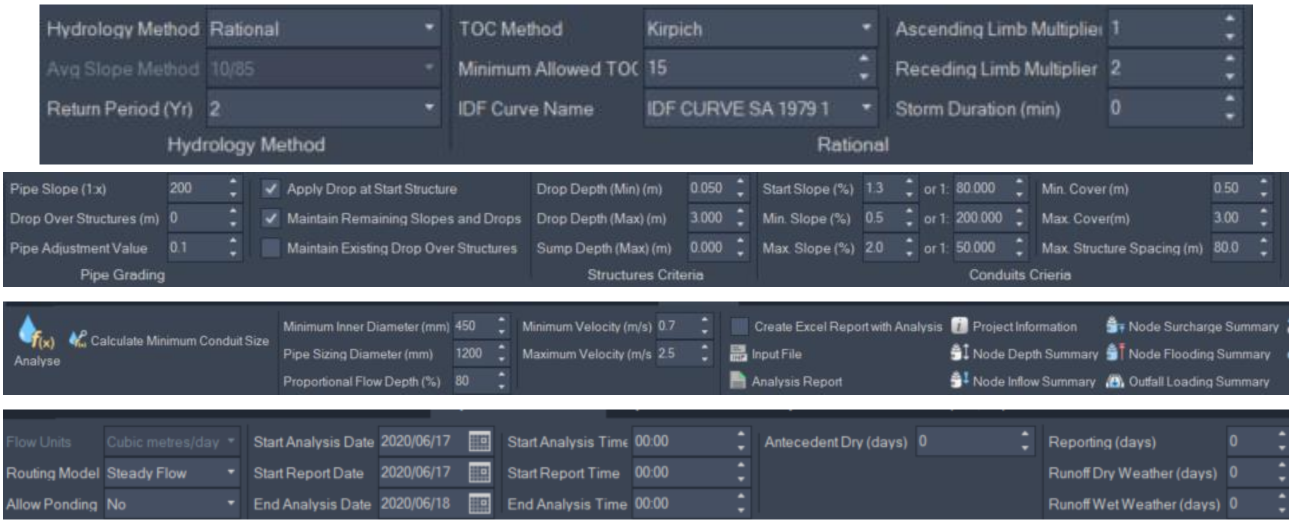


Figure 10: Analytical Capabilities Available using Devotech iDAS Pipe Manager

With all these options available, the municipal engineering professional can now make an informed decision using intelligent, dynamic and intuitive BIM technologies to arrive at the optimal solution promoting economical and sustainable civil infrastructure delivery.

From a construction perspective, information such as setting out data, positioning, etc can be exported to a report or tabulated and included with the construction drawings, with the construction drawings typically following the format of plan and profile, with the plan view of the pipe network displayed above the long section of the respective pipe branch. With the adoption of cloud technologies and remote connectivity accelerated due to the COVID pandemic, the model of the stormwater network and associated layouts can be shared using a common data environment (CDE), enabling all involved to be connected in an environment catered to professionals in the architecture, engineering & construction (AEC) industry. The benefits of BIM and a CDE are numerous, such as the streamlined communication between design and construction teams, ensuring that issues raised on site are immediately communicated to the consultant, resulting in less delay time and problem resolution, all from a mobile device. Project tracking, reports, revisions, approvals, claim certificates, site logs, etc can all be executed and housed in this CDE, promoting faster service delivery and project completion.

QUANTIFICATION OF STORMWATER NETWORK

Now that the municipal engineering professional is satisfied with the stormwater network design and all design criteria are met, quantification of the network is required to determine construction costs. With the power of BIM 3D modeling and South African Standards, these quantities can be derived, with the excavations calculated as per SABS 1200 specifications, with sample outputs portrayed below

Excavation Depth Increments (m): 1.0 Calculate Export BOM

Excavation Parameters
Excavation Volume (m³)
Excavation Volume Summary (m³)
Excavation Length (m)
Excavation Length Summary (m)
Pipes and Structures

	Pipe name	Part Size	Reference Surface	Bedding Class	Side Allowance (mm)	Message	Total Excavation
6	P1.1	600mm Class 75D	Final Surface	Class A	300.000	<None>	18.715
7	P1.2	600mm Class 75D	Final Surface	Class A	300.000	<None>	14.514
8	P1.3	600mm Class 75D	Final Surface	Class A	300.000	<None>	33.557
5	P1.4	600mm Class 75D	Final Surface	Class A	300.000	<None>	489.283
4	P1.5	600mm Class 75D	Final Surface	Class A	300.000	<None>	77.744
2	P1.6	600mm Class 75D	Final Surface	Class A	300.000	<None>	151.516
3	P1.7	600mm Class 75D	Final Surface	Class A	300.000	<None>	43.624
19	P1.8	600mm Class 75D	Final Surface	Class B	300.000	<None>	72.300

Figure 11: Excavation Quantities Calculated as per SABS 1200 using Devotech iDAS Pipe Manager

	Part Size	Total Excavation	Bedding Cradle	Compacted Selected Fill Blanket	Refill	0.00-1.00m	1.00-2.00m	2.00-3.00m	3.00-4.00m	4.00-5.00m
1	600mm Class 75D	2248.790	294.570	534.190	1420.029	930.281	846.041	371.703	71.938	5.987
Total		2248.790	294.570	534.190	1420.029	930.281	846.041	371.703	71.938	5.987

Minimum Diameter (mm)	Maximum Diameter (mm)	Side Clearance (mm)
0	125	300
125	700	300
700	1000	400
1000	2000	500
2000	10000	600

Structures

Structure Count Summary

Type	Quantity
Inlet	9
Manhole	14
Outfall	1

Pipes

Type	Length (m)
600mm Class 75D	727.231m
Total:	727.231m

Figure 12: Calculated Network Quantities using Devotech iDAS Pipe Manager

PIPE LIST-STORMWATER

PIPE NAME	START INVERT LEVEL	END INVERT LEVEL	3D LENGTH TO INSIDE EDGES	SLOPE	DIAMETER AND CLASS
P1.1	1471.870	1471.700	10.026	1.579%	600mm Class 75D
P1.2	1471.650	1471.499	6.597	1.986%	600mm Class 75D
P1.3	1471.449	1468.377	8.417	35.301%	600mm Class 75D
P1.4	1468.327	1467.580	125.222	0.593%	600mm Class 75D
P1.5	1467.530	1465.985	27.285	5.547%	600mm Class 75D
P1.6	1465.935	1465.342	51.796	1.122%	600mm Class 75D
P1.7	1465.292	1464.477	17.495	4.478%	600mm Class 75D
P1.8	1464.427	1464.264	32.164	0.500%	600mm Class 75D

STRUCTURE LIST-STORMWATER

STRUCTURE NAME	Y	X	RIM ELEVATION	SUMP ELEVATION SUMP DEPTH	INVERT ELEVATION	MATERIAL
KI1.1	26 088.156	2 842 358.084	1473.019	1471.870 1.148	P1.1-INV OUT 1471.870	Concrete
KI1.2	26 032.753	2 842 221.829	1468.522	1467.530 0.992	P1.4-INV IN 1467.580 P1.5-INV OUT 1467.530	Concrete Concrete
MH1.1	26 080.501	2 842 350.463	1472.877	1471.650 1.227	P1.1-INV IN 1471.700 P1.2-INV OUT 1471.650	Concrete Concrete
MH1.2	26 073.129	2 842 348.695	1472.754	1471.449 1.305	P1.2-INV IN 1471.499 P1.3-INV OUT 1471.449	Concrete Concrete
MH1.3	26 066.464	2 842 343.096	1472.548	1468.327 4.221	P1.3-INV IN 1468.377 P1.4-INV OUT 1468.327	Concrete Concrete
MH1.4	26 024.576	2 842 195.202	1468.533	1465.935 2.598	P1.5-INV IN 1465.985 P66-INV IN 1465.985 P72-INV IN 1465.985 P1.6-INV OUT 1465.935	Concrete Concrete Concrete Concrete

Figure 13: Tabulated Network Quantities in Autodesk Civil 3D

CONSTRUCTION DOCUMENTATION

Construction drawings such as plan a profile can then be generated using the functionalities provided by Autodesk Civil 3D & Devotech iDAS. With the dynamic nature of BIM, these drawings are linked to the model, ensuring that any modifications made and reflected.

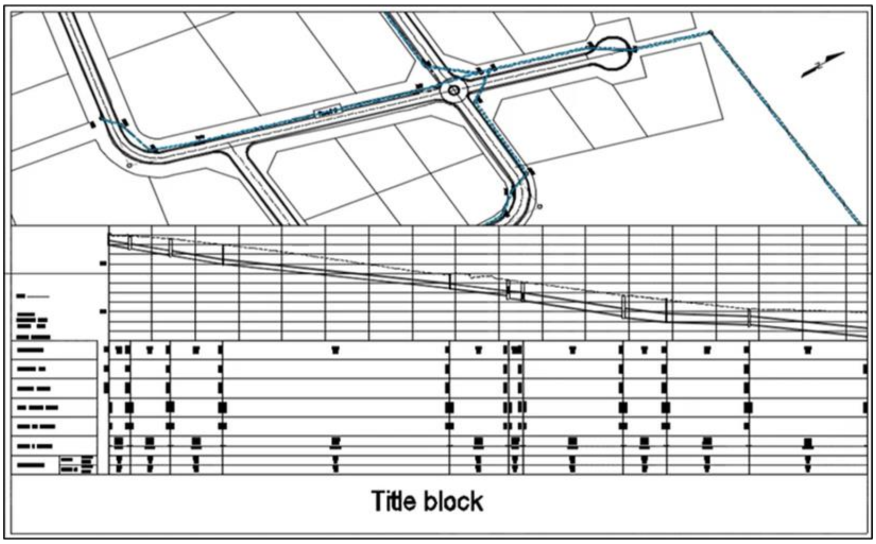


Figure 14: Plan & Profile View Sheet of a Stormwater Network using Autodesk Civil 3D & Devotech iDAS