Attachment 3

Local Water Management Strategy

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LOCAL WATER MANAGEMENT STRATEGY

Mariginiup Precinct 8

QUBMARI01
09/04/2024

Document Status

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Executive summary

Planning framework

This Local Water Management Strategy (LWMS) has been prepared to support the Mariginiup – Precinct 8 Local Structure Plan (LSP) of the Mariginiup landholding within the City of Wanneroo (The City). LSP approval is being sought for the site which comprises approximately 264.1 ha of passive rural land, which includes market gardens, a plant nursery, and other rural commercial pursuits in the suburb or Mariginiup. Precinct 8 is located approximately 25 km north of Perth CBD and 5 km from the Joondalup Train station/centre and freeway. The subject site is predominantly zoned "urban deferred", with a small section in the northwest region zoned "rural" and Lake Mariginiup and surrounds, located in the south-east, zoned "parks and recreation" under the Metropolitan Region Scheme (MRS). A request will need to be lodged with the Western Australia Planning Commission (WAPC) to lift the Urban Deferment (once the original reasons for deferral have been addressed) as part of the project delivery.

The objective of this LWMS is to demonstrate that the land has the capacity to support the proposed land use change identified in the LSP and that the LSP can appropriately manage water (flooding, surface water, and groundwater). Precinct 8 is identified within "Stage 1" in Figure 1.16 of the EWDSP (August 2021). DWER in its advice to DPLH indicated it would consider development within "Stage 1" provided that appropriate land is being set aside for flood management and the future connection to a district scale groundwater management scheme.

Tis LWMS indicates that the project (Precinct 8) has sufficient clearance to groundwater levels (including future predicated groundwater levels) and that development won't require subsoil drainage to be installed. The absence of the need for subsoil drainage indicates that a future connection to a district scale groundwater management scheme is not required. The LWMS also indicates the flood management requirements including an assessment of cumulative flood impacts to the water levels within lake Mariginiup and Little Mariginiup. The cumulative flood impact assessment indicates that the instantaneous flood height does not present a risk to the LSP implementation as the anticipated difference between future lake water levels and the finished lot levels surrounding the lake will have well in excess of the separation distance or freeboard required.

This LWMS will recognise the principles, objectives, and requirements of total water cycle management as outlined in the *State Planning Policy 2.9 Water Resources* (Government of WA, 2006), *Liveable Neighbourhoods* (WAPC, 2007) and the *Stormwater Management Manual for WA* (DWER, 2004 – 2007), including the *Decision process for stormwater for stormwater management in WA* (DWER, 2017). The LWMS will also broadly state the water quantity and quality management objectives to be achieved.

The proposed development will include total water cycle management principles and objectives guided by the *Better Urban Water Management Framework* (WAPC 2008).

LWMS key elements

Key elements of this LWMS are presented in Table 1.

Table 1: LWMS key reporting elements

LWMS elements	Design objectives/comments
Introduction (Section 1)	▪ Qube Property (Qube) is seeking Local Structure Plan approval for Precinct 8 which is an area of approximately 264.1 ha comprised predominantly of passive rural land located in Mariginiup. ▪ The site is currently predominantly zoned 'Urban deferred', with a small section in the north-west region zoned 'Rural' and Lake Mariginiup and surrounds, located in the south-east, zoned 'Parks and recreation' under the Metropolitan Region Scheme (MRS).

	▪ A request will need to be lodged with the WAPC to lift the Urban Deferment as part of the project delivery. ▪ A MRS Amendment process is also required to reserve public land uses, namely reservation of Primary Distributor Roads, Integrator Arterial Roads, Parks and Recreation Reserves, Transit Corridors and High School reserves.
Topography (Section 0)	▪ Surface elevation across the site ranges from 41 metres above height datum (mAHD) in the low-lying Lake Mariginiup in the south of the site to 71 mAHD in the northern portion of the site. ▪ The topography of the site is comprised of Spearwood and Bassendean low dune systems running in a north-south direction.
Geology (Section 2.4)	▪ Geology mapping indicates the majority of the site is underlain by Spearwood Sands (S7). Spearwood sands typically consist of pale and olive yellow, medium to coarse grained, subangular quartz with traces of feldspar of residual origin. The lower elevation areas are mapped as being underlain by Peaty clay (Cps) of lacustrine origin typified by dark grey and black clays with variable sand content. ▪ The Spearwood Sands comprise of sands with high permeability but low nutrient retention which prevents the discharge of increased nutrient loads to the downstream environment. This presents implications for future development. ▪ The superficial formation is underlain by the Jandabup, Mariginiup subareas while the Wanneroo confined subarea as part of the Leederville and Yarragadee formation.
Groundwater (Section 2.11)	▪ The site is underlain by the Superficial, Leederville and Yarragadee aquifers. ▪ Local hydrology is dominated by infiltration and evapotranspiration with almost no runoff due to the highly conductive sandy soils on site. ▪ Regional groundwater contours indicate that the historical maximum groundwater level (MGL) at the site ranges from approximately 39 mAHD in the south-westernmost corner of the site to 43 mAHD on the eastern boundary of the site. ▪ Site specific monitoring was undertaken between September 2009 and October 2010 and in 2021, with maximum (calibrated) groundwater across the site during 2021 ranging from 40.12 to 44.11 mAHD. ▪ Depth to groundwater recorded during 2021 monitoring ranged from 1.73 mbgl (MB01 in September 2021) to 25 mbgl (MB06 in July 2021). ▪ Groundwater flow is generally east to west. ▪ The AAMGL within the site ranges from approximately 44 to 38.5 mAHD.
Surface water (Section 2.12)	▪ The site contains two major depression areas: Lake Mariginiup and Little Mariginiup Lake. Surface water flows into these depression areas and there is no defined drainage system that directs surface water out of the site area.
Wetlands (Section 2.9)	▪ Two Conservation Category wetlands (CCW) are mapped within the site boundary: Lake Mariginiup (ID 7953) and Little Mariginiup Lake (ID 8161). CCW wetlands support a high level of attributes and functions and are considered the highest priority wetlands. ▪ One of the wetlands located on site (Lake Mariginiup) is associated with cultural heritage values.
Water source planning (Section 3)	▪ The site is located outside all Underground Water Pollution Control Areas (UWPCA) and the site will be serviced via the existing potable water supply scheme. ▪ It is proposed that approximately 197,608 kL/yr will be required to irrigate POS.

	▪ Qube currently holds an annual groundwater allocation of 33,050 kL/yr, however the use of this licence needs to be confirmed. The allocation is insufficient to cover the required irrigation demand alone. ▪ No groundwater resources are available for allocation in the aquifers beneath Precinct 8 at present. ▪ Qube will be required to transfer existing groundwater licences during the acquisition of new properties that contain existing licences or through trades for existing licences and land use changes across the precinct and district.
Water conservation strategies (Section 4)	▪ Landscape packages which adopt Waterwise principles will be encouraged. ▪ Detailed landscape plans for POS areas will be provided at subdivision stage which detail the proposed landscape treatments, plantings, community facilities and integration of drainage areas with the POS landscape design.
Stormwater management (Section 5)	▪ The first 15 mm of rainfall to be infiltrated close-to-source or treated in bioretention basins within each catchment to mimic predevelopment conditions. ▪ The site consists of trapped and discharging catchments. ▪ Runoff generated in trapped catchments is managed via retention basins which are sized to infiltrate up to the 1% AEP event. ▪ The first 15 mm of runoff generated in discharging catchments will be treated in bioretention basins. Runoff in larger events will be conveyed to Little Mariginiup Lake or Lake Mariginiup. ▪ A cumulative flood impact assessment indicates that the cumulative inflows and resulting instantaneous lake water level rise does not present a risk to proposed urban development surrounding Lake Mariginiup based on an assessment of lake water levels and the proposed finished earthworks levels across Precinct 7 and 8.
Groundwater management (Section 0)	▪ Given the separation between the design surface and the proposed Controlled Groundwater Level (CGL), it is not anticipated that subsoil drainage is a significant design constraint for Precinct 8. ▪ Subsoils may be installed beneath parts of the project area as a contingency against rising groundwater levels but at this stage are not contingent on a district scale groundwater management scheme
Monitoring and reporting (Section 7)	▪ Quarterly groundwater levels and quality monitoring will be undertaken for a period of 3 years following practical completion, with a review after 18 months. ▪ Quarterly surface water levels and quality monitoring will be undertaken for a period of 3 years following practical completion, with a review after 18 months.
Potential future monitoring requirements (Section 8)	▪ Section 8 provides details of UWMP requirements and the roles and responsibilities related to implementation of the LWMS.

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1. Introduction

1.1. Purpose

This Local Water Management Strategy (LWMS) has been prepared on behalf of Qube Property (Qube) to support the Mariginiup – Precinct 8 Local Structure Plan (LSP) of the Mariginiup landholding within the City of Wanneroo (The City) (Figure 1). LSP approval is being sought for the site which comprises approximately 264.1 ha of passive rural land as well as a plant nursery, a dog trainer, a door supplier, a homewares store and two florists in the suburb or Mariginiup.

1.2. Planning background

The LSP is part of the East Wanneroo District Structure Plan (DSP). The DSP was prepared to guide land use planning and development of approximately 8,300 hectares (ha) across a small portion of Pinjar, most of Mariginiup and Jandabup, the eastern part of Wanneroo, Gnangara, and south-west Lexia. The DSP was approved by the West Australian Planning Commission (WAPC) in August 2021.

1.3. Planning context

The subject site is predominantly zoned “urban deferred”, with a small section in the northwest region zoned “rural” and Lake Mariginiup and surrounds, located in the south-east, zoned “parks and recreation” under the Metropolitan Region Scheme (MRS). A request will need to be lodged with the Western Australia Planning Commission (WAPC) to lift the Urban Deferment (once the original reasons for deferral have been addressed) as part of the project delivery.

A state-run MRS Amendment process is also required to reserve public land uses, namely reservation of Primary Distributor Roads, Integrator Arterial Roads, Parks and Recreation Reserves, Transit Corridors and High School reserves.

1.4. Proposed structure plan

The LSP covers approximately 264.1 ha and will be developed to provide housing, a local centre, primary school and public open space (POS). The LSP is shown in Appendix A.

Figure 1: Site plan and location

1.5. Design objectives

This LWMS is in accordance with State Planning Policy 2.9: Water Resources (Government of WA 2007) and has been developed with reference to the following guidance documents:

- Interim: Developing a Local Water Management Strategy (Department of Water, 2008)
- Better Urban Water Management (Western Australian Planning Commission, 2008)
- Stormwater Management Manual for Western Australia (Department of Water, 2004–2007)
- Liveable Neighbourhoods (Western Australian Planning Commission, 2003)
- Water resource considerations when controlling groundwater levels in urban development (Department of Water, 2013)
- Draft Specification separation distances for groundwater controlled urban development (IPWEA, 2016)
- Decision Process for Stormwater Management in Western Australia (DWER, 2017)

The LWMS details the integrated water management strategies to facilitate future urban water management planning. The LWMS will achieve integrated water management through the following design objectives:

- Protection of important environmental assets and water resources
- Deliver functional and integrated public open space
- Manage flooding and inundation risks to human life and property
- Ensure the efficient re-use of water resources

1.6. Key documents and previous studies

A number of on-site investigations have been completed and relied upon to prepare this LWMS including:

- District Water Management Strategy (Urbaqua, 2021)
- East Wanneroo District Structure Plan (DPLH, 2021)
- Environmental Assessment Report (PGV Environmental 2024)
- Engineering Servicing Report (JDSi 2024)
- Infiltration testing Proposed Drainage Swales Precinct 8, East Wanneroo, Mariginiup (Galt Geotechnics, 2023)

2. Existing environment

2.1. Site location and existing and historical land use

Precinct 8 is located approximately 25 km north of Perth CBD and approximately 5 km to the Joondalup Train station/centre and freeway. The site is comprised of undeveloped land with scattered vegetation and agricultural land. The site consists of the following lots:

- 32, 40, 62, 82, 98, 104, 110, 112 and 118 Coogee Rd
- 171 Mariginiup Rd
- 11, 39 and 61 Mornington Drive
- 26 Pinelake Trail
- 240, 252, 252L, 264, 264L, 274, 274L and 294 Pinjar Rd
- 10, 11, 26, 46, 55, 56, 68, 90, 91, 100, 100L, 101 102, 111, 112, 113 and 121 Ranch Rd

Table 2 is a summary of the main current land uses and structures associated with the site from a review of available geographic information systems.

Table 2: Site land uses

Lot	Industry/Land Use	Risk to water quality
82 Coogee Rd 264 and 294 Pinjar Rd	Nursery	Yes
46 Ranch Rd	Homewares store	Yes
98 Coogee Rd	Dog trainer	No
101 Ranch Rd	Door supplier	Yes
32, 40, 62, 104 and 110 Coogee Rd 171 Mariginiup Rd 39 and 61 Mornington Drive 10, 11, 68, 90, 100, 102 and 121 Ranch Rd 274 Pinjar Rd	Agricultural land	Yes
112 and 118 Coogee Rd 11 Mornington Drive 26 Pinelake Rd 240, 25, 252L, 264, 264L and 274L Pinjar Rd 26, 55, 91, 100L, 111, 112 and 113 Ranch Rd	Bush	No

2.2. Climate and rainfall

2.2.1. Baseline

The site is typical of the Swan Coastal Plain being warm and dry during summer and cooler and wetter during the winter period. Baseline rainfall (1961-1990 as defined by DWER, 2015) at Mariginiup is 773.3 mm by using data drill output, which interpolates rainfall between nearby stations, refer to Table 3 and Figure 2. Rainfall between 1990 to 2021 is 3.8% lower than the baseline rainfall at 732.4 mm.

Baseline pan evaporation (E_{pan}) for Mariginiup is approximately 1,800 mm based on BOM mapping (BOM 2023a). The potential evapotranspiration (PET) for Mariginiup is approximately 1,400 mm based on BOM mapping (BOM, 2023b), which equates to ~0.78 E_{pan}. A climate summary is provided in Table 3.

Table 3: Climate and rainfall data

Weather statistic (mm/mt)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline rainfall (1961-1990)	12.2	13.7	14.0	44.0	100.9	165.4	159.1	115.3	74.7	43.8	21.6	8.6	773.3 mm
Rainfall (1990-2017)	15.2	15.6	19.5	36.0	90.7	135.4	148.2	119.4	78.5	40.3	24.3	9.3	732.4 mm
Baseline pan evaporation (E_{pan})													1,800 mm
Baseline potential evapotranspiration (PET)													1,400 mm

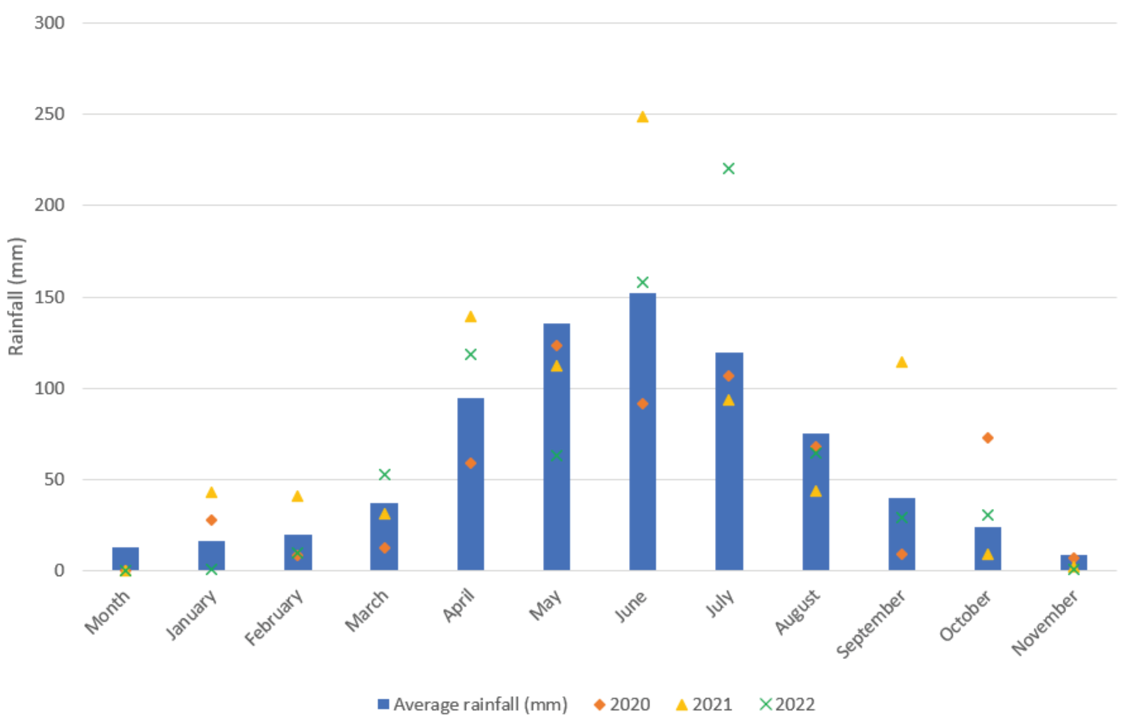

Figure 2: Historical average monthly rainfall (1986-2022) (BoM Site 9105, Wanneroo)

2.3. Topography

Topographic contours indicate elevation across the site ranges from 41 metres above height datum (mAHD) in the low-lying Lake Mariginiup in the south of the site to 71 mAHD in the northern portion of the site as shown in Figure 3.

The topography of the site is comprised of Spearwood and Bassendean low dune systems running north-south direction.

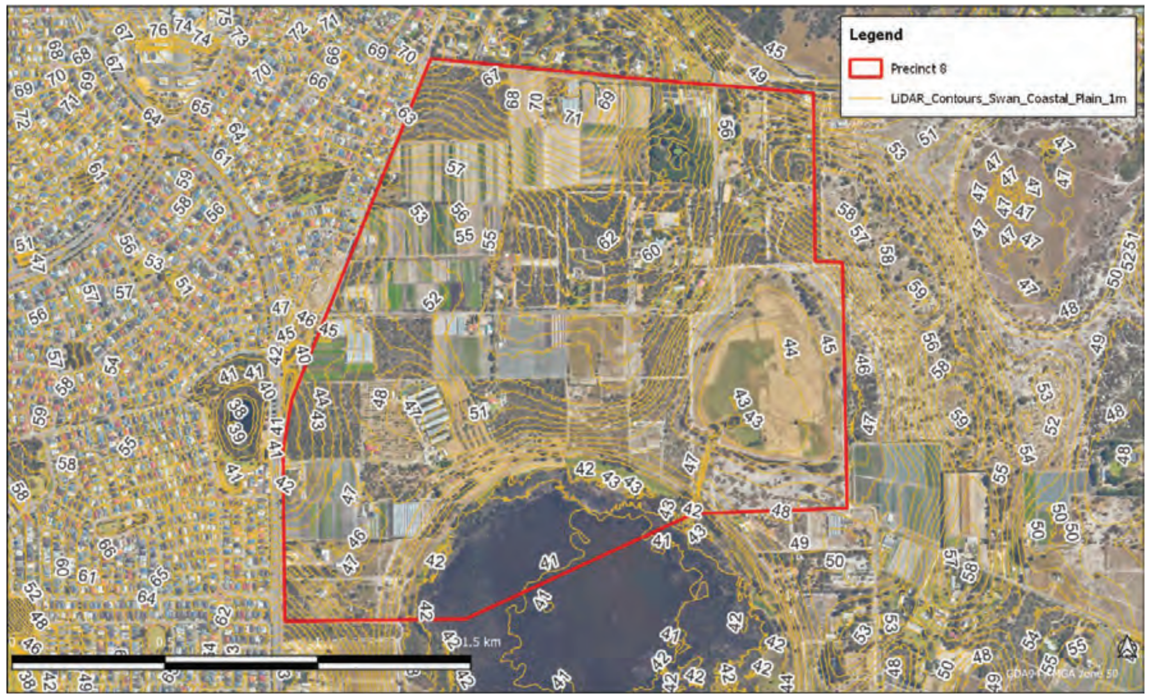

Figure 3: Site topography

2.4. Geology

2.4.1. Regional mapping

Geology mapping indicates the majority of the site is underlain by Spearwood Sands (S7) (Figure 4). Spearwood sands typically consist of pale and olive yellow, medium to coarse grained, subangular quartz with traces of feldspar of residual origin. The lower elevation areas are mapped as being underlain by Peaty clay (Cps) of lacustrine origin typified by dark grey and black clays with variable sand content.

The Spearwood Sands comprise of sands with high permeability but low nutrient retention which prevents the discharge of increased nutrient loads to the downstream environment. This presents implications for future development.

The superficial formation is underlain by the Jandabup, Mariginiup subareas while the Wanneroo confined subarea as part of the Leederville and Yarragadee formation.

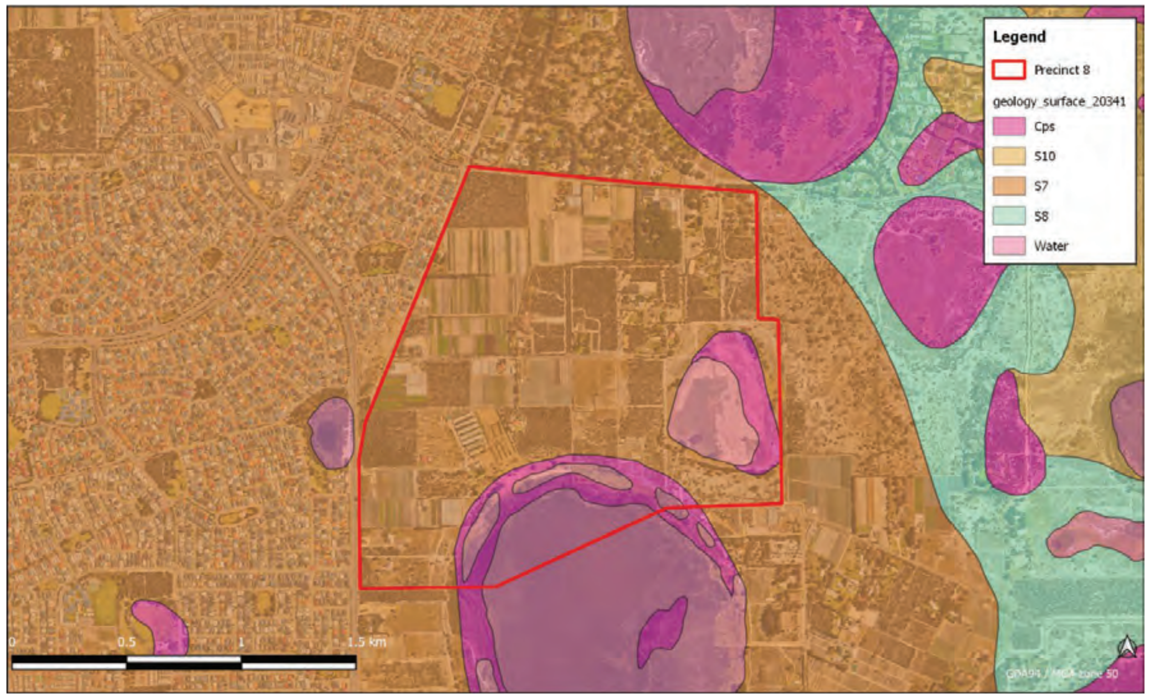

Figure 4: Site geology

2.4.2. Site investigations

A technical memorandum was prepared by Galt (Galt, 2023) presenting the outcomes of Galt's infiltration testing at eleven proposed swale locations across the subject site. Infiltration testing comprised the drilling of two machine auger boreholes extending to a target depth of 3 m for each location, and infiltration testing using the inverse auger hole technique in each borehole at depths typically ranging from approximately 2.75 m to 2.90 m below ground.

The main results from the infiltration testing include:

- The topsoil was predominantly sandy, fine to coarse grained, and sub-angular to sub-rounded. Similar subsoils were encountered at most locations
- Groundwater was generally not encountered at the locations, except for one location in the west which encountered groundwater at a depth of 1.5 mbgl,
- Minimum unsaturated hydraulic conductivity ranged from 0.7 m/day to >15 m/day.

The technical memorandum is included as Appendix B.

2.5. Acid sulfate soils

The low-lying Lake Mariginiup and Little Mariginiup Lake are areas having 'High to Moderate Risk' of Acid Sulfate Soils (ASS) as per the ASS risk mapping shown in Figure 5 (DWER, 2017). Areas of ASS cannot be confirmed or removed at this stage of the development and will need to be determined by an ASS investigation, potentially with sampling the site. Due to this risk, there will be a requirement for an ASS Management Plan to be prepared as part of the development and subdivision of the site.

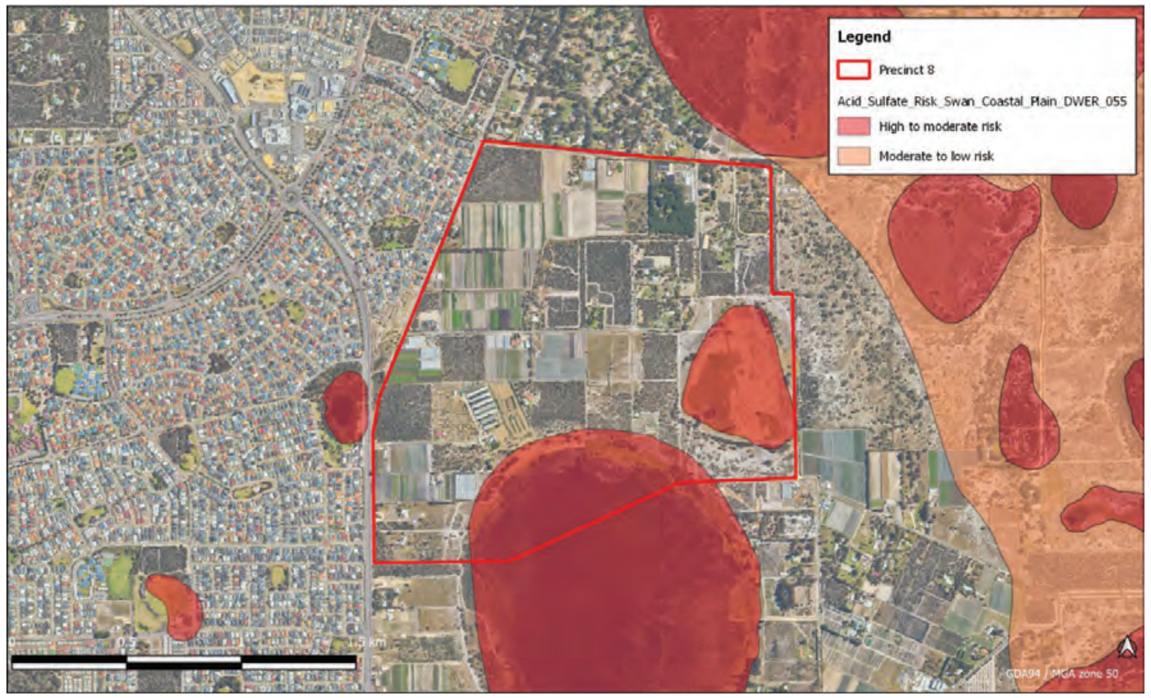

Figure 5: Acid Sulfate Soil mapping

2.6. Contaminated sites

A review of the DWER Contaminated Sites Register did not identify any known contaminated site under Section 11 of the Act within the Site or in the immediate surrounds. There are several sites where the former land use may present a contamination risk. These risks will need to be investigated as part of local structure planning and subdivision process.

2.7. Aboriginal Heritage

Lake Mariginiup, located in the southern portion of the site, is identified as an Aboriginal Heritage site (ID 3741) (Figure 6). The proposed area to be developed within the site is not within the Aboriginal Heritage site. A heritage enquiry of the site identifies that the subject site is on the land within or adjacent to the Whadjuk People Indigenous Land Use Agreement.

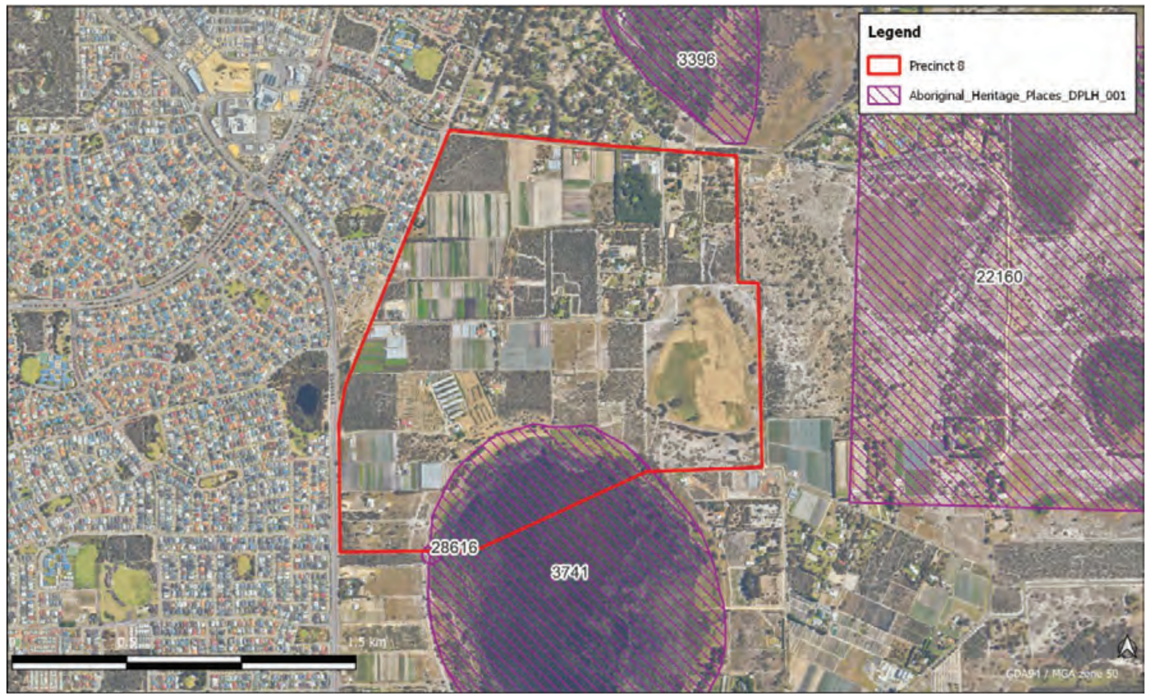

Figure 6: Aboriginal Heritage

2.8. Bush Forever sites

A search of the Western Australian Local Government Association Administrative Planning Categories mapping tool (WALGA, 2018) identified Lake Mariginiup and Little Mariginiup Lake as Bush Forever sites (ID 147), as presented in Figure 7.

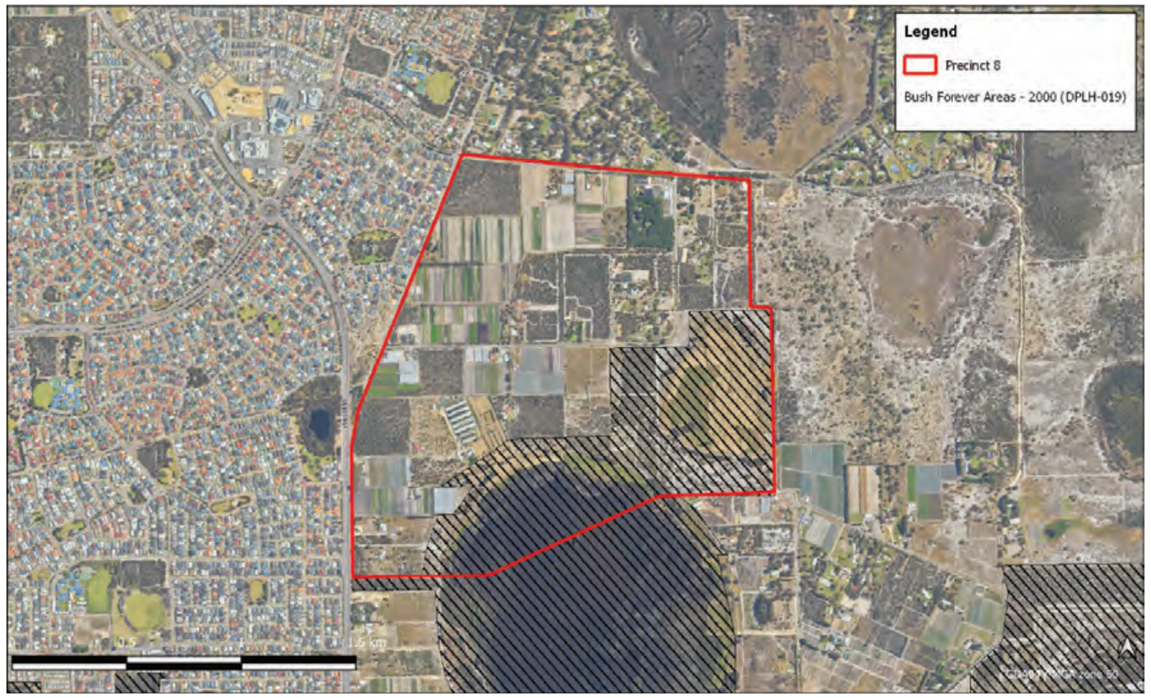

Figure 7: Bush Forever

2.9. Wetlands

Two Conservation Category wetlands (CCW) are mapped within the site boundary: Lake Mariginiup (ID 7953) and Little Mariginiup Lake (ID 8161) (Figure 8). Such wetlands support a high level of attributes and functions and are considered the highest priority wetlands. These areas will require preserving and protecting, with no development, clearing or any activity that may lead to further loss or degradation permitted.

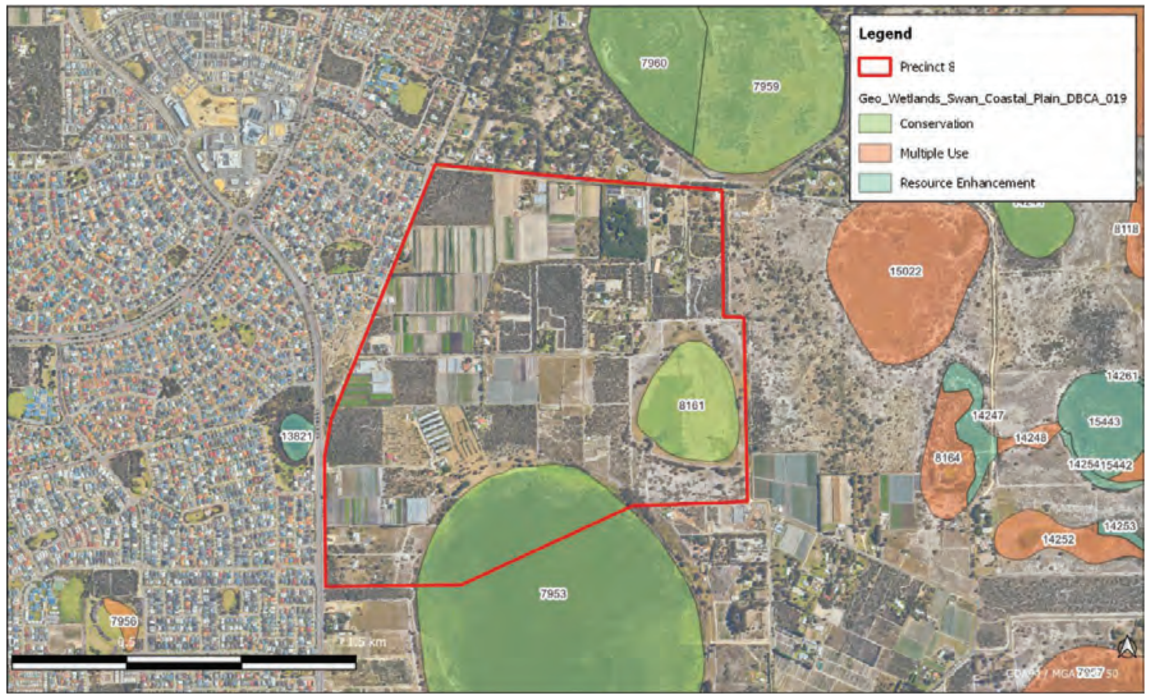

Figure 8: Wetlands

2.10. Public Drinking Water Source Areas

There are no Public Drinking Water Source Areas (PDSWAs), Water Corporation bores or Wellhead Protection Zones mapped within the site boundary (DWER,2018) (Figure 9).

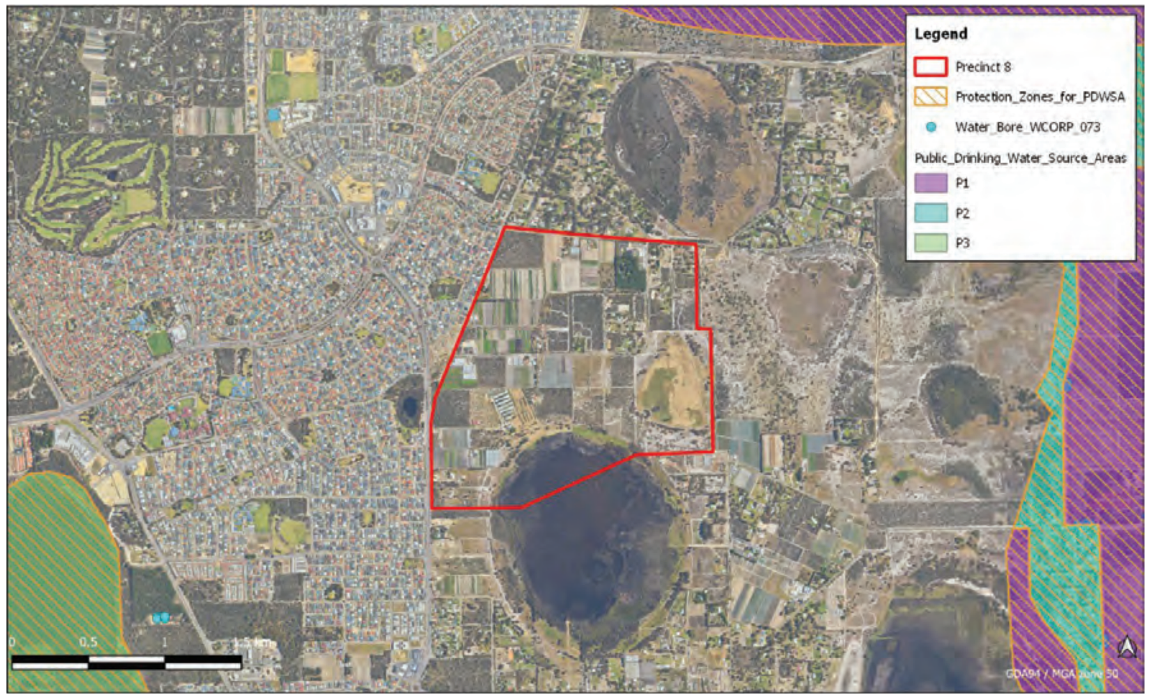

Figure 9: PDWSA and Wellhead Protection Zones

2.11. Groundwater

2.11.1. Aquifers

The site is situated on the Swan Coastal Plain and in the Wanneroo groundwater area. There are three groundwater sub-areas associated with the site: Wanneroo Confined, Mariginiup and Jandabup. This site is part of the Wanneroo groundwater system which comprises of the following hydrogeological units (aquifers), including the:

- Unconfined Superficial aquifer
- Confined Leederville aquifer
- Confined Yarragadee aquifer

Local hydrology is dominated by infiltration and evapotranspiration with almost no runoff due to the highly conductive sandy soils on site (refer Section 2.4.1). Infiltrated rainwater is expected to directly recharge to the Wanneroo groundwater system as it does in the bordering Gnangara groundwater system. Surface water is generally confined to Lake Mariginiup and Little Mariginiup Lake which are surface expressions of the Superficial aquifer in low lying land.

Regional groundwater mapping indicates groundwater across the site generally flows from east to west (DWER, 2023a).

2.11.2. Regional groundwater levels

The Perth Groundwater Map (DWER, 2023a), which provides an indication of regional groundwater levels, shows the historic Maximum Groundwater Level (MGL) at the site to be approximately 43 mAHD on the eastern boundary of the site. The lowest historic MGL on site is approximately 39 mAHD and is mapped in the south-westernmost corner of the site.

2.11.3. Groundwater levels

Several groundwater monitoring bores were installed as a part of a study undertaken by RPS (RPS, 2011). Monitoring was undertaken monthly between September 2009 and October 2010.

Eight groundwater monitoring bores were installed and monitored monthly by Emerge in 2021 with the objective to capture the annual winter peak and for future use undertaking pre- and post-development monitoring. Peak groundwater levels are detailed in Table 4.

Table 4: Pre-development peak groundwater levels (Emerge, 2021)

Bore ID	Easting	Northing	Peak winter groundwater level (mAHD) (calibrated)	Peak winter groundwater level (mAHD)
MB01	386776.391	6490333.755	40.12	40.12
MB02	388681.337	6490089.475	43.76	43.76
MB03	388563.549	6490883.064	43.93	43.93
MB04	387907.767	6490731.772	43.17	48.07
MB05	387123.546	6491074.224	44.11	44.11
MB06	387535.232	6491503.924	42.60	46.26
MB07	388564.692	6491423.921	44.00	44.00
MS7	387224.11	6489706.56	42.04	42.04

Groundwater levels across the site ranged from a minimum 39.2 mAHD (MB01, November 2021) to 47.4 mAHD (MB04, November 2021) during the 5-month monitoring period.

Groundwater contours were produced using monitoring data, with the process involving the removal of outliers (MB04 and MB06 in November and August respectively recorded values 4 to 5 m higher than the previous month) and calibration of monitored data against the historic winter peak recorded at the DWER bore (MS7, WIN ID 61610688, October 1992) (refer Figure 10).

Relative to mapped surface levels, peak groundwater levels ranged from 1.73 metres below ground level (mbgl) at MB01 in September 2021 to a maximum of 25 mbgl at MB06 in July 2021. Contours indicate groundwater generally flows east to west, consistent with regional mapping.

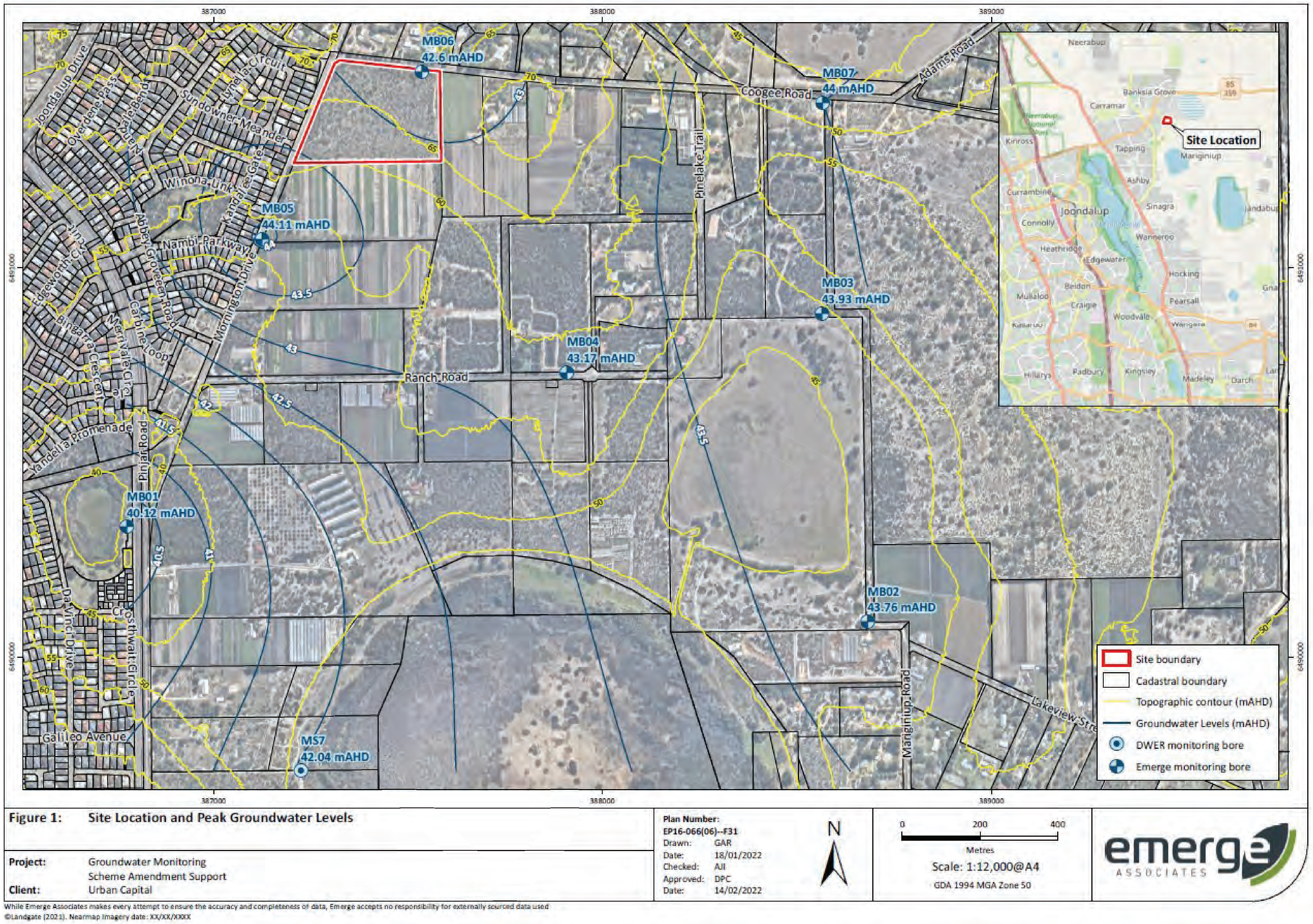

Figure 10: Peak groundwater levels (Emerge, 2021)

2.11.3.1. AAMGL calculation

The 1986 to 1995 AAMGL was determined for the EWDSP area as follows:

- Shallow bores across the EWDSP area were identified from Water Information Reporting data (DWER, 2023b). For this assessment, shallow bores were those in which the top of the screen was less than 15 m below the average 1986 to 1995 water level in the bore. Where there were groups of nested or adjacent bores, the highest screened bore that had a mostly complete set of water level data was selected for the CGL.
- Water level data from these bores was extracted from the Water Information Reporting database (DWER, 2023b).
- 90 shallow screened bores were selected for the estimation of the CGL, 85 of which had 8 or more years of maximum (winter) water levels measured between June and November. For these bores the AAMGL was calculated as the average of the annual maximum water levels.
- The remaining 5 bores had 6 or less years of maximum winter water level data. For these bores the AAMGL was calculated by adjusting the measured maximum water level to an AAMGL, using an average adjustment estimated from the 80 bores that had a complete data record.
- The lakes within the EWDSP area are throughflow wetlands, so are expressions of the groundwater table. An AAMGL was estimated for the lakes that had measured surface water levels over the period from 1986 to 1995, including Lake Mariginiup, Lake Jandabup, Lake Gnangara, Lake Adams, and Lake Badgerup.
- The calculated AAMGL for Lake Mariginiup and Lake Jandabup were compared to the Gnangara Mound Criteria (Government of Western Australia, 2009) and water thresholds presented in both the DWMS (Urbaqua, 2021) and a recent review of the thresholds (Kavazos et al., 2020). The calculated AAMGLs for each of these lakes was within the preferred range of lake water levels (i.e., the AAMGL was above the preferred minimum peak water level (spring) and below the absolute maximum peak.
- The CGL surface was generated by contouring (using a kriging analysis) the bore and lake AAMGL values across the EWDSP area.
- The CGL within the vicinity of Precinct 8 is shown in Figure 11, with depth to CGL across the site shown in Figure 12. Figure 13 shows depth to CGL across the site, highlighting depths to CGL shallower than 5 m.

In the absence of long-term groundwater level data for the site, the 1986 to 1995 AAMGL has been adopted for the site.

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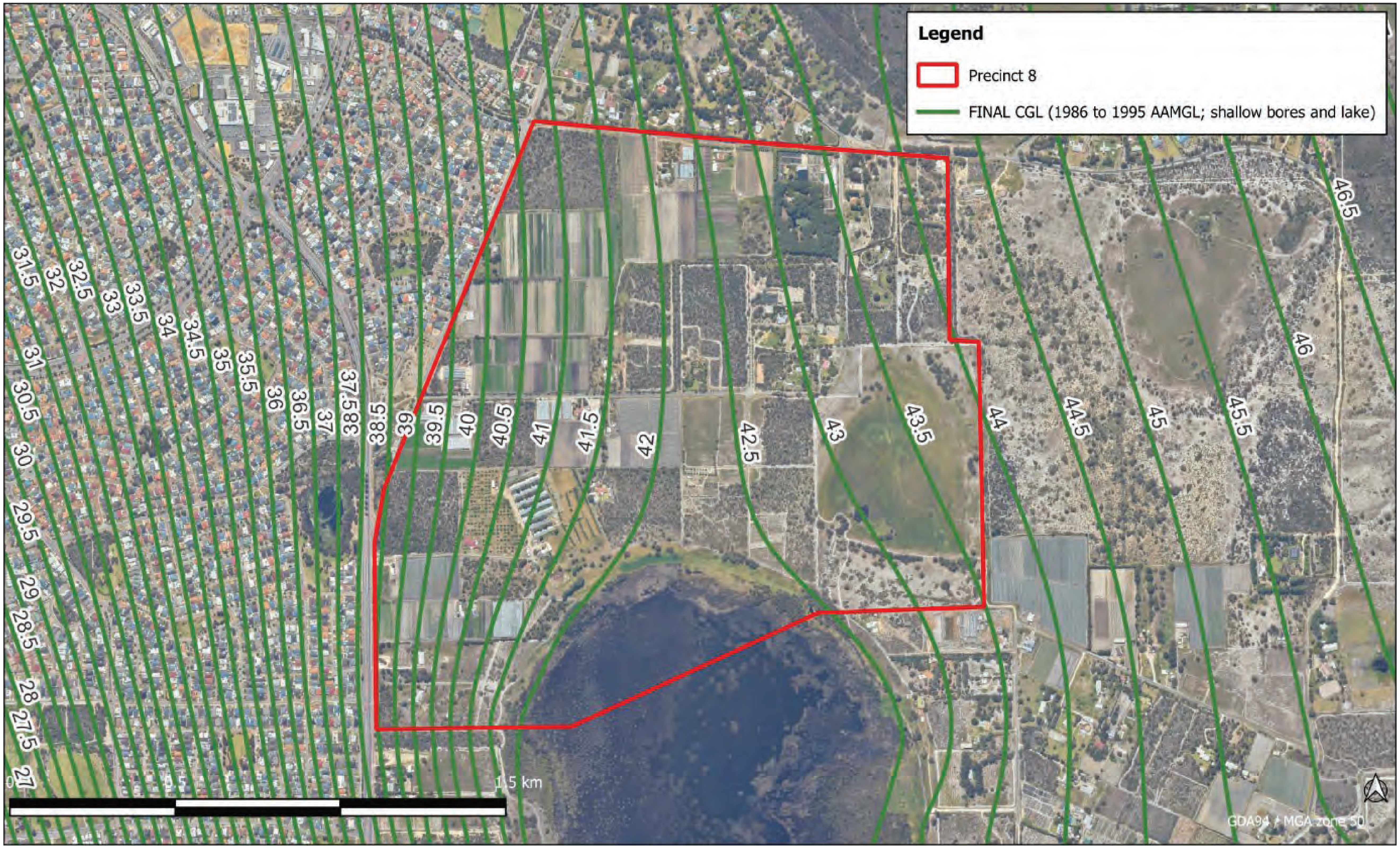

Figure 11: AAMGL/adopted CGL (1986 to 1995)

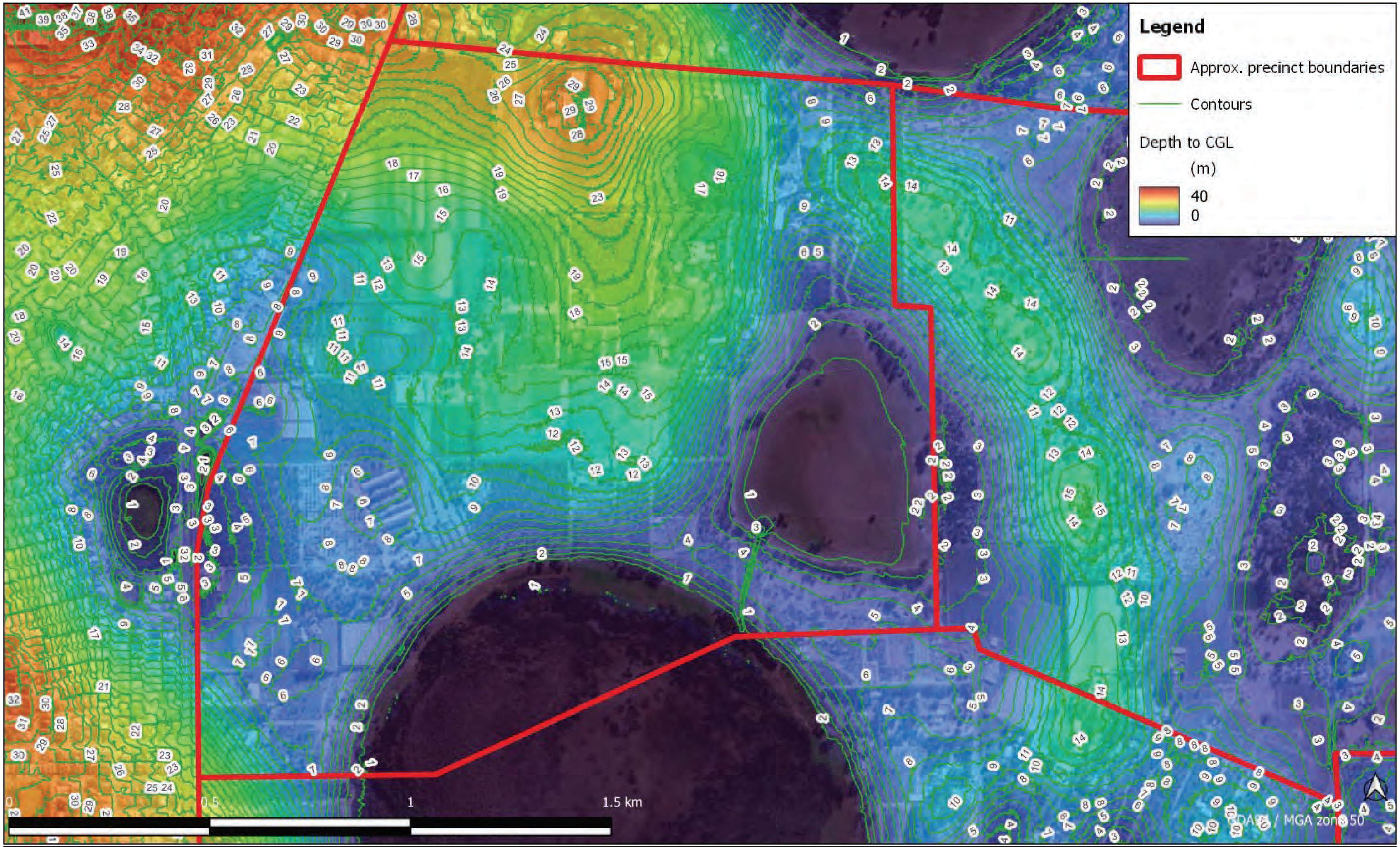

Figure 12: Depth to adopted CGL from existing surface level

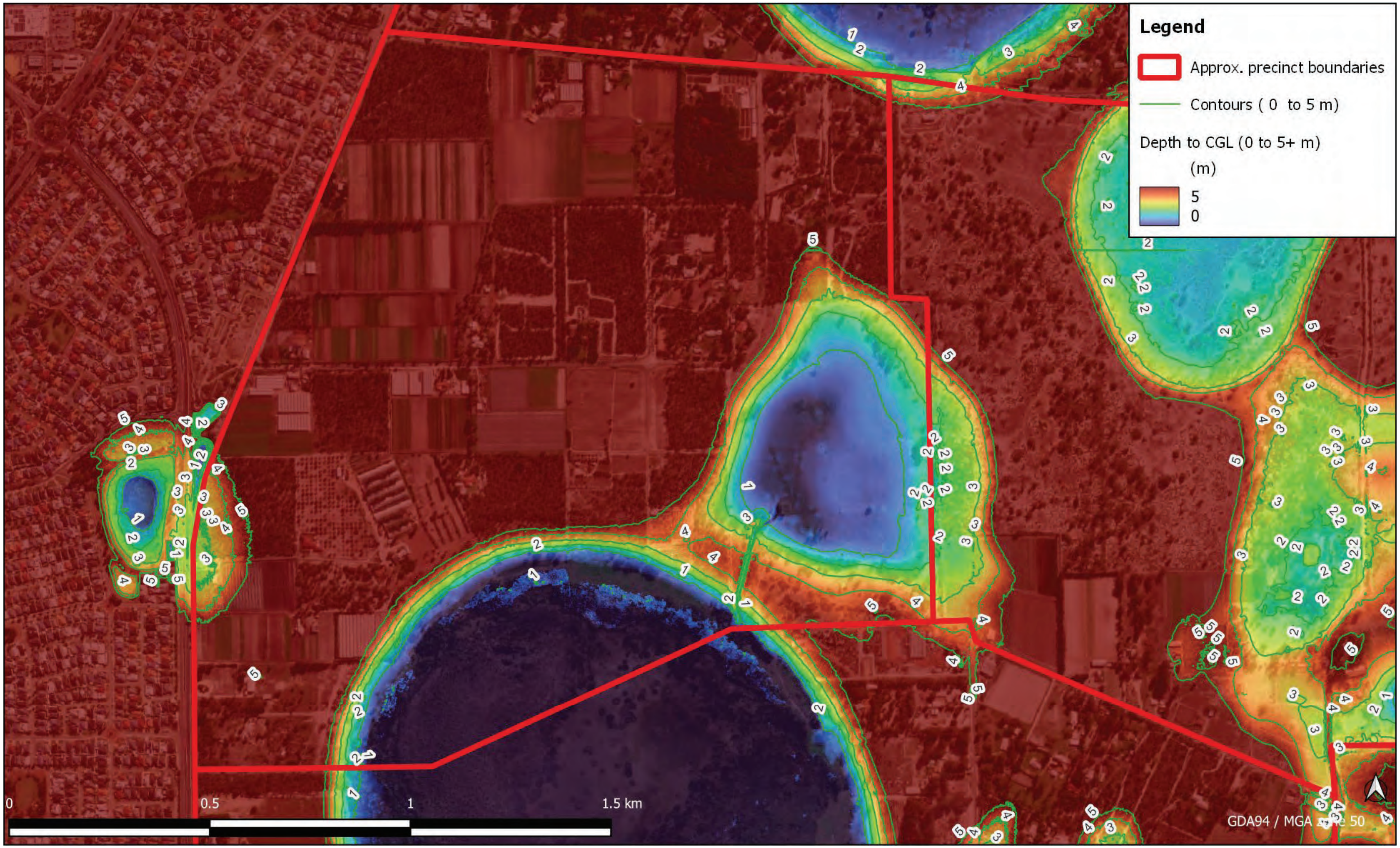

Figure 13: Depth to adopted CGL, showing area with >5 m clearance to surface level

Maximum groundwater levels recorded on site in 2021 (as discussed in Section 2.11.3) were generally consistent with the AAMGL across the site (0.25 m lower in the north-east corner and 2.12 m higher in the south-west corner of the site). As outlined in Section 2.11.3, rainfall recorded for the 2021 at the closest BoM weather station (Wanneroo, BoM 9105) was higher than average historical rainfall (1986 to 2022) across a number of months. As the maximum groundwater levels were recorded in the months following months of high rainfall, and without more recent long-term site-specific groundwater data, it is still recommended that the 1986 to 1995 AAMGL is adopted for the site.

2.11.3.2. MGL discussion

The proposed CGL for the EWDSP area is the 1986 to 1995 average annual maximum groundwater level (AAMGL) as discussed in Section 2.11.3.1 and as was endorsed through the DWMS (Urbaqua, 2021).

2.11.4. Groundwater quality

Two rounds of groundwater quality monitoring were undertaken at the seven Emerge bores in August and October 2021, as detailed in Table 5 below.

Groundwater was generally moderately acidic, exceeding ANZECC (2000) guidelines at all bores except for MB06 and Electrical Conductivity (EC) exceeding ANZECC guidelines at all bores except for MB07. Total Nitrogen (TN) and Total Phosphorus (TP) concentrations in groundwater exceeded all relevant guideline values except for MB03. High TN concentrations can potentially be a result of surrounding land uses where market farms highly populate the sites surrounding area.

No other groundwater quality monitoring is known to have been undertaken within the site.

Table 5: Average site groundwater quality (Emerge, 2021)

Bore ID	pH	EC	DO	TN	TP
	-	µS/cm	mg/L	mg/L	mg/L
ANZECC guideline values	*6.5-8*	*120-300*	*NG*	*1.2*	*0.065*
Short-term HRAP target concentrations	-	-	-	*2.0*	*0.2*
Long-term HRAP target concentrations	-	-	-	*1.0*	*0.1*
MB01	5.445	827.5	1.465	18	4.225
MB02	5.325	517.5	3.01	18.35	0.695
MB03	4.135	968.5	3.23	1.95	0.185
MB04	5.5	488	3.9	4.65	0.875
MB05	5.95	1199.5	3.72	53.3	0.76
MB06	6.835	780.5	2.04	31.8	0.915
MB07	3.68	267.65	0.795	4.55	0.445

NG No Guideline

2.12. Surface hydrology

The site contains two major depression areas: Lake Mariginiup and Little Mariginiup Lake. Surface water flows into these depression areas and does not have a defined drainage system that directs surface water out of the site area. Surface water features are shown in Figure 14.

Figure 14: Site hydrology

2.12.1. Catchment hydrology

Lake Mariginiup and Little Mariginiup Lake are the only mapped natural waterways located on site. These areas as well as a low-lying area in the southwest corner of the site experience minimal separation between land surfaces and groundwater levels.

2.12.2. Pre-development flood modelling

A pre-development 1-dimensional surface water model of the entire East Wanneroo DSP area was constructed to provide an estimate on the likely volumes and top water levels in key wetlands during minor and major flood events (Urbaqua, 2021). It was noted that the increase to top water levels from the storage of surface water in key wetlands (including Lake Mariginiup) from major and minor events was not considered to be significant (Urbaqua, 2021).

2.12.3. Surface water quantity and flow monitoring

Lake level monitoring of Lake Mariginiup has been undertaken at a single surface water monitoring site (WIR ID 6162577) on a roughly monthly basis since 1954 (DWER, 2023b). Monitoring since 2000 indicates lake levels have ranged from dry (approximate surface elevation of 41.3 mAHD) to 41.85 mAHD (recorded in October 2000).

No other known surface water quantity or flow monitoring has been undertaken on site.

2.12.4. Surface water quality monitoring

Surface water quality monitoring of Lake Mariginiup is recorded to have been historically undertaken across a total of 30 monitoring locations, 28 of which were only monitored in 2007, one of which (WIR ID 6162577) has been monitored since 1954 and one of which (WIR ID 6164637) was monitored from October 2013 to October 2022. A summary of water quality analysis is detailed in Table 6.

Table 6: Lake Mariginiup water quality results (DWER 2023b)

Parameter	ANZECC (2000) guideline[1]	Data count	Minimum	Maximum	Average
EC (µS/cm)	*NG*	30	700	2,900	1,489

Parameter	ANZECC (2000) guideline[1]	Data count	Minimum	Maximum	Average
pH	*6.5 – 8.0*	61	3.41	7.45	5.09
TSS (mg/L)	*NG*	3	3	5	3.67
TN (mg/L)	*1.5*	13	1.6	16.2	5.72
TKN (mg/L)	*NG*	12	1.5	16.2	5.63
TP (mg/L)	*0.05*	8	0.01	0.07	0.03

[1]ANZECC (2000) Wetland Guidelines for slightly – moderate disturbed ecosystems

NG No Guideline

The water quality results indicate that Lake Mariginiup is strongly acidic, with the average pH exceeding ANZECC (2000) Wetland guidelines for slightly – moderate disturbed ecosystems. All Total Nitrogen (TN) concentrations and the maximum Total Phosphorus (TP) concentration recorded at the lake exceeded the relevant guideline values. Ongoing sampling will be required in future development stages to ensure water quality is not further degraded by development.

3. Water source planning

3.1. Potable water supply

The site is located outside all Underground Water Pollution Control Areas (UWPCA) and the site will be serviced via the existing potable water supply scheme.

3.2. Non-potable water supply

3.2.1. Requirements

As per the water conservation principle of "No potable water should be used outside of homes and buildings with the use of water to be as efficient as possible" in *Better Urban Water Management* (WAPC, 2008).

3.2.2. Irrigation demand analysis

The irrigation demand for Precinct 8 is estimated as 197,608 kL/year, as detailed in Table 7. The estimates are based on an irrigation rate of 7,500 kL/Ha/year for irrigated POS and school areas, and 10,000 kL/Ha/year for the school oval. The POS areas presented in Table 7 exclude areas of retained vegetation, playgrounds, and large hardstand or paved spaces located within those POS areas.

Qube Pinelake Development Pty Ltd currently hold an annual groundwater allocation of 33,050 kL, however the use of this licence needs to be confirmed and will need to be supplemented to cover the residual irrigation demand. It is anticipated that current groundwater licence holders will trade or transfer their licences as urban development progresses across the precinct and land use changes from market gardens to urban development.

Table 7: Irrigation demand estimate

	Total Area (Ha)	Irrigation % of area	Irrigated Area (Ha)	Irrigation Rate (kL/Ha/yr)	Total Water Demand (kL/yr)
Public Open Space	25.69	90%	23.12	7,500	173,408
School	2.80	20%	0.56	7,500	4,200
Co-located School oval	2.0	100%	2.0	10,000	20,000
Total	**30.49**	**-**	**25.68**	**-**	**197,608**

3.2.3. Groundwater allocation availability

The DSP site is located within the Wanneroo groundwater area. The following aquifers are present in the area:

- Perth – Superficial Swan (Unconfined, Mariginiup subarea).
- Perth – Leederville (Confined, Wanneroo Confined subarea).
- Perth – Yarragadee North (Confined, Wanneroo confined subarea).

Pentium Water has completed an analysis of the currently available groundwater allocations in the underlying aquifers (within Precinct 8) and adjoining groundwater subareas. Pentium Water requested a groundwater resource allocation report from DWER on 28 August 2023, which is a document that outlines the groundwater allocation status. No groundwater resources are available for allocation in the aquifers beneath Precinct 8 (the Mariginiup groundwater subarea as illustrated in Figure 15). No groundwater allocation will be made available by DWER, and no new groundwater licence will be provided to Qube for the irrigation of POS within Precinct 8 as it currently stands.

Figure 15 below shows Precinct 8 including the groundwater subarea and the groundwater licence areas respectively. The Mariginiup groundwater licence areas outline the current groundwater licences within Precinct 8 that could be traded or transferred to Qube. The details of these existing licences are outlined in Table 8.

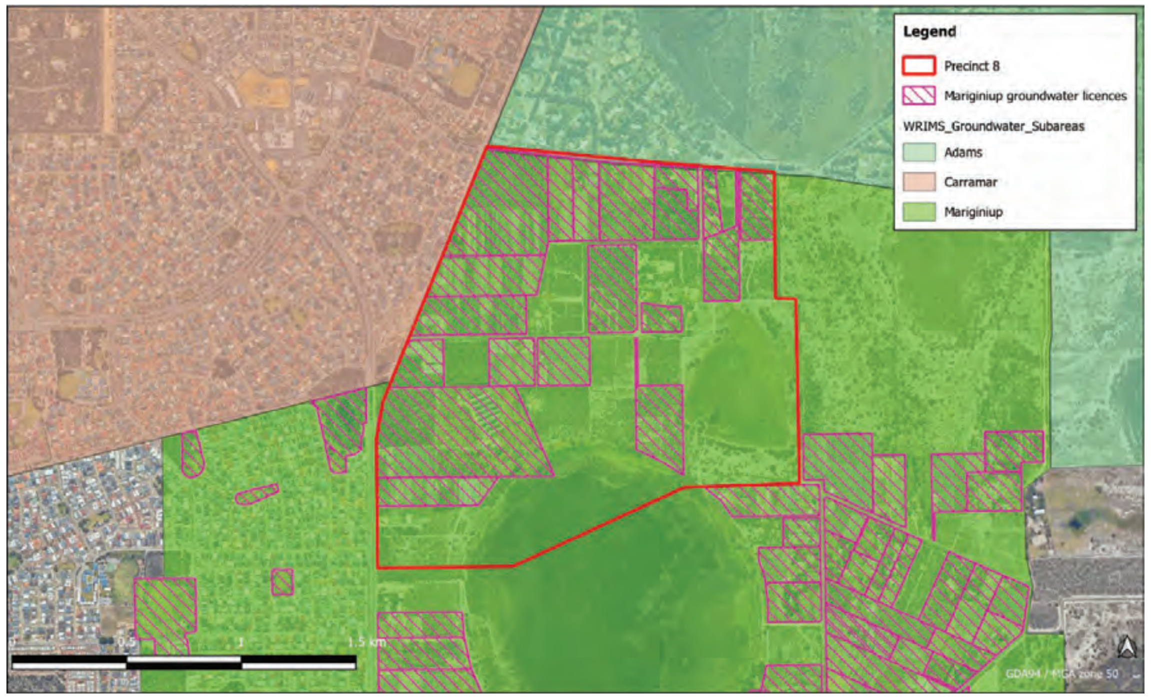

Figure 15: Groundwater subareas

3.2.4. Groundwater allocation transfers or licence trading

There are mechanisms in place for trading and transfers of groundwater licences under the *Right in Water and Irrigation Act 1914*. Each application is assessed on an individual, transparent, and equitable basis in accordance with the requirement of the Act.

It is noted that groundwater licences within Precinct 8 are associated predominantly with market garden activities. Given the proposed development of the area will require a change in land use from market gardening to residential development, it can reasonably be expected the transition via a trade or transfer of these groundwater licences (from the horticulturalists) to be available for transfer to the Precinct's land development proponents or directly to the City of Wanneroo for future irrigation requirements.

The licences outlined in Table 8 could be transferred to Qube should Qube continue to acquire land within Precinct 8. Alternatively, Qube could look to trade for these licences with the existing owners outside of a land acquisition deal.

Table 8: Groundwater licences within Precinct 8 and their respective subareas

Lot number	Owner(s) & Licence Address	Groundwater Licence Number(s)	Groundwater Allocation (kL)	Aquifer	Subarea
L1	**Do, Thanh Thinh;** Lot 1 Pinjar Rd, Mariginiup	78896	56,900	Superficial	Mariginiup
L39	**Lenzo Investments Pty Ltd;** Lot 39 Pinjar Rd, Mariginiup	45534	106,550		
L250, L1 and L7	**Do, Thuong Le, Dinh, Thanh Duc;** Lot 250 Ranch Rd, Lot 1 Ranch Rd and Lot 7 Coogee Rd, Mariginiup	153426	148,200		
L3	**Marinovich, John;** Lot 3 Ranch Rd, Mariginiup	157853	45,650		
L4	**Staltari, Guiseppe;** Lot 4 Ranch Rd, Mariginiup	93599	63,000		
L11	**Western Australian Planning Commission;** Lot 11 Ranch Rd, Mariginiup	45431	6,300		
L3	**Tran, Van Hua;** Lot 3 Mornington Dr, Mariginiup	89920	102,000		
L5 and L4	**Urban Capital Carramar Pty Ltd;** Lot 5 Mornington Dr and Lot 4 Mornington Dr, Mariginiup	151330	34,905		
L101, L501, L502, L503 and L504	**Danti, Eric Peter, Danti, Anne Lesley;** Lot 101, 501, 502, 503 and 504 Honey St, Mariginiup	49704	30,750		
L102	**Urban Capital Carramar;** Lot 102 on Plan 29470 and being the whole of the land comprised in Certificate of Title Volume 2520	108196	56,050		
L7	**Chrispi Investments Pty Ltd;** Lot 7 Coogee Rd, Mariginiup	66754	68,150		
L21	**Harken, Edward, Zanetic, Sally;** Lot 21 Pinelake Trail, Mariginiup	89279	15,150		
L20	**Qube Pinelake Development Pty Ltd;** Lot 20 Coogee Rd, Mariginiup	83336	33,050		
L24	**JIWA Holdings Pty Ltd as trustee for the JIWA Unit Trust;** Lot 24 Coogee Rd, Mariginiup	207381	4,000		
L6	**Schad, Thomas, Schad, Marion;** Lot 6 Coogee Rd, Mariginiup	58317	9,750		

Lot number	Owner(s) & Licence Address	Groundwater Licence Number(s)	Groundwater Allocation (kL)	Aquifer	Subarea
L3	**Coogee Road Investments Pty Ltd;** Lot 3 Coogee Rd, Mariginiup	57186	15,200		
Total Allocation available in the superficial aquifer within Precinct 8 (excluding the licence already held by Qube)			762,555 kL/yr		

3.3. Wastewater servicing

The site, as well as all developments within the East Wanneroo DSP area, are to comply with the requirements of the *Government Sewerage Policy* (DPLH 2019). Facilities across the site (POS, residential lots etc.) are proposed to be connected to deep sewerage (refer Engineering Servicing Report included in Appendix C).

4. Water conservation strategies

4.1. Proposed strategy

The State Water Plan (2007) is a strategic policy and planning framework to meet the state's water demands to the year 2030. One of the key targets is to reduce potable water consumption to 40 kL–60 kL per person per year. Water conservation measures will be adopted at the site to create a "Waterwise" development and minimise water-servicing requirements. The water conservation strategy will aim to reduce water demand through incorporating a variety of effective initiatives. These are described in more detail below.

4.2. Water conservation measures

The development will adopt the following water conservation measures:

- A Waterwise landscaping strategy which utilises largely native plant species with limited exotic species in select areas only to provide feature planting.
- Front yard Waterwise landscaping packages may be promoted to new home buyers. These may include the use of plant species with low water requirements, minimal turf, mulch, and soil conditioner to increase water retention.
- An outdoor private swimming pool or spa associated with a Class 1 building must be supplied with a cover or blanket.
- All internal hot water outlets (such as taps, showers and washing machine water supply fitting) must be connected to a hot water system or a recirculating hot water system with pipes installed and insulated in accordance with AS/NZS3500.
- Lot owners will be encouraged to install greywater systems for irrigation of individual household landscaping.
- Lot owners will also be encouraged to install rainwater tanks. Rainwater tanks can be connected to water using fixtures such as toilets, washing machines and external taps to reduce potable water demand.

4.3. Water appliances and fittings

As a minimum, builders will be required to fit Waterwise appliances and fittings within all display homes at the site. This will include the use of water efficient taps, showers, and water heating systems as well as Waterwise garden designs and irrigation schemes. Educational material will be made available via the use of education boards and pamphlets within display homes.

4.4. Waterwise landscaping

Landscape plans for POS areas will be provided at subdivision stage which detail the proposed landscape treatments, plantings, community facilities and integration of drainage areas with the POS landscape design. A preliminary landscape design is provided in Appendix E.

The following general principles will be adopted wherever possible in the landscape design:

- Promote the use of native plants with low water and fertiliser requirements.
- Promote landscape treatments sympathetic to climate conditions and prevailing site conditions – e.g. soil types, topography, environment, wetlands etc.
- Utilise "cluster or clump" plantings to provide useable shade areas and better use of reticulated water in preference to single item or symmetrical planting regimes.
- Irrigate grass and garden areas at appropriate time so as to reduce evaporative loss and minimise transpiration losses.
- Ensure that irrigation regime is responsive to prevailing weather conditions.

5. Stormwater management

5.1. Drainage principles and criteria

The key aspects and principles of stormwater management to be adopted for the site as outlined in the DWMS (Urbaqua, 2021) are outlined below:

- Small rainfall events are to be managed at source (in lots and streets) wherever possible.
- All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.
- Where the depth to groundwater is limited and subsurface drainage systems are required, the design of at source stormwater infiltration systems should be informed by consideration of the interaction between infiltrated stormwater and the CGL.
- Where it is not feasible to retain or infiltrate small rainfall events at source without impacting amenity, the use of systems such as rainwater tanks, raingardens and detention tanks should be considered as alternatives to more traditional systems.

The key design criteria for the site are outlined in Table 9 and have been established in accordance with the design objectives outlined in Section 1.5. The preliminary drainage catchment plans and concept earthworks engineering design are presented as Appendix D.

Table 9: Water management objectives and how these will be achieved.

Objective	Design criteria
Stormwater	
Ecological protection (15 mm event)	▪ The aim of 1 EY-45 minutes (~15 mm) storm event is to capture and treat the first flush of rainfall runoff from lots and road reserves to minimise the export of pollutants. ▪ Maintain the pre-development hydrological regime by encouraging infiltration close-to-source. Manage the 15mm rainfall depth through infiltration, retention and/or treatment.
Conveyance (20% AEP event)	▪ Provide sufficient drainage system capacity for the critical 20% AEP (5-year ARI) event to maintain serviceability of roads and pedestrian areas. ▪ Runoff to be detained an infiltrated via trapped basins, or outlet into Little Mariginiup Lake or Lake Mariginiup.
Flood protection (1% AEP event)	▪ Provide adequate flood retention storage. ▪ Runoff to be detained an infiltrated via trapped basins, or outlet into Little Mariginiup Lake or Lake Mariginiup. ▪ Habitable floor levels to be at least 0.3 m above the 1% AEP flood level of the urban drainage system and road reserve, and a minimum of 0.5 m above the floodplain levels in Lake Mariginiup, Little Mariginiup Lake and trapped low basins. ▪ Roads will be passable with a maximum water depth on the road pavement of 0.2 m. ▪ Runoff in the critical 1% AEP event from the site into Lake Mariginiup and Little Mariginiup Lake will result in an increase flood depth of 0.63 m and 0.33 m respectively. Stormwater modelling indicates that both lakes have capacity to receive this runoff without presenting any flood risk to adjacent landholdings.
Mosquito management	▪ Swales and basins will be designed so that retained stormwater will be infiltrated within 96 hours following storm events to prevent mosquito and midge breeding conditions.
Groundwater	
Groundwater level control	▪ Finished lot levels within the site will have a minimum clearance from CGL of approximately 3 m. ▪ Basin inverts will generally have a clearance of at least 2 m from CGL.
Stormwater	
Nutrient management	▪ The swales and basins will be designed to retain nutrients using amended soils and appropriate plant species selection.

5.2. Post development catchments

Post development, the site will consist of 30 stormwater catchments as presented in Figure 16 and Table 10. The concept earthworks design and preliminary drainage catchment plan (JDSi 2023) is provided in Appendix D.

Surface water catchments located within the site are characterised as either trapped or discharging. Runoff generated in trapped catchments will be managed in retention basins which are sized to store and infiltrate up to the 1% AEP event. The first 15 mm of runoff generated in discharging catchments will be treated in bioretention basins and in larger events runoff will discharge into Little Mariginiup Lake or Lake Mariginiup.

The land use breakdown within each catchment is detailed in Table 10 below.

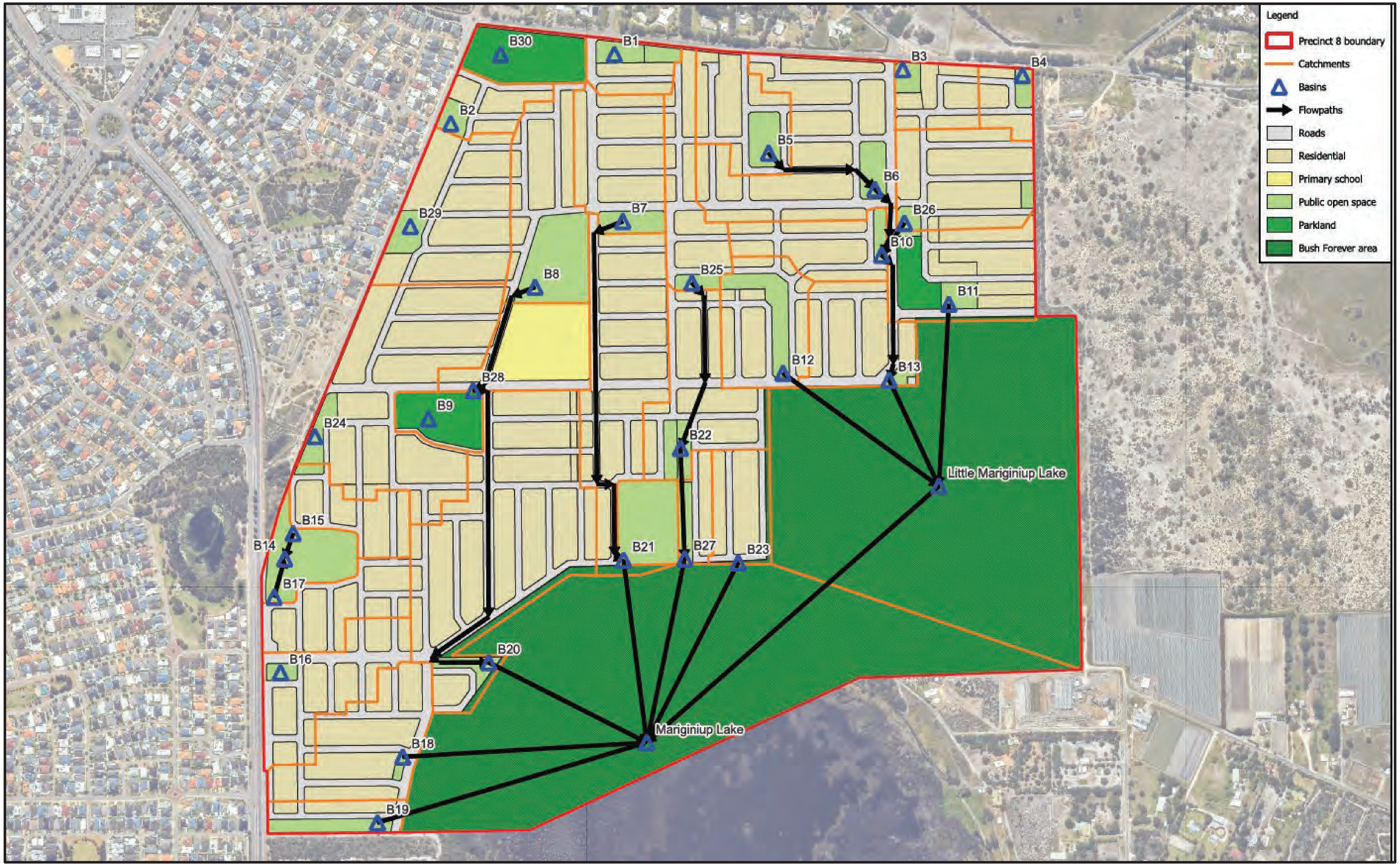

Figure 16: Catchment areas and basin locations

Table 10: Post development land use breakdown

Basin ID	Total area (ha)	POS/ Drainage (ha)	Tree Reserve / Wetland (ha)	Road reserve (ha)	Residential and school lots (ha)
B1	2.416	0.8688	0	0.464	1.083
B2	2.431	0.441	0	0.597	1.393
B3	2.561	0.415	0	0.644	1.502
B4	1.946	0.323	0	0.487	1.136
B5	4.719	0.896	0	1.147	2.676
B6	11.847	0.7606	0	3.326	7.760
B7	6.186	0.7545	0	1.629	3.802
B8	7.334	2.7835	0	1.365	3.185
B9	2.086	0	2.086	0	0
B10	4.359	0.3276	0	1.209	2.822
B11	6.206	0.418	1.1392	1.395	3.254
B12	5.523	1.2757	0	1.274	2.973
B13	5.638	0.2231	0	1.624	3.790
B14	2.953	0	2.953	0	0
B15	3.371	0	0	1.011	2.360
B16	5.316	0.2782	0	1.511	3.526
B17	4.245	0	0	1.274	2.972
B18	5.993	0.5292	0	1.639	3.825
B19	3.478	0.3435	0	0.940	2.194
B20	20.373	0.4016	0	5.991	13.980
B21	10.748	0	0	3.224	7.524
B22	7.308	0.8	0	1.952	4.556
B23	3.362	0.2	0	0.949	2.213
B24	13.835	0.526	0	3.993	9.316
B25	4.762	0.347	0	1.325	3.091
B26	6.895	0.306	0	1.977	4.612
B27	1.784	0.596	0	0.356	0.832
B28	4.491	0	0	1.347	3.144
B29	8.145	0.401	0	2.323	5.421
B30	3.129	0	3.129	0	0

5.3. Stormwater management strategy

5.3.1. Minor drainage system including the small (15mm) event

5.3.1.1. Lot drainage >300 m^2

Residential lots greater than 300 m^2 in size will be fitted with soakwells within the lot boundary sized to infiltrate the first 15 mm of rainfall.

5.3.1.2. Road reserve

Road runoff will drain to at-source infiltration solutions (i.e. rain gardens, tree pits) swales or to basins via a pit and pipe system that will provide bioretention treatment for up to the first 15 mm of rainfall runoff.

Managing small rainfall events via close-to-source infiltration will effectively mimic the pre-development hydrological regime of the site and reduce both the volume and peak flow rate of stormwater discharging into Lake Mariginiup or Little Mariginiup Lake.

5.3.1.3. Other land use types

The first 15 mm of rainfall from schools or other land use types will be retained within the lot boundaries using soak wells, rainwater tanks or other WSUD methods.

5.3.1.4. Bioretention treatment

The effective impervious area was calculated within each catchment as 10% of residential and school lots; and 80% or road reserve area, as summarised in Table 11. Bioretention treatment will be provided for the first 15 mm of rainfall that falls on effective impervious areas and runoff will be treated and infiltrated within bioretention basins.

The proposed bioretention basin area within the site totals 1.2432 ha which equates to more than 2% of the total effective impervious. Infiltration rates assumed within each basin based on the infiltration testing. Infiltration rates and bioretention basin sizing is detailed in Table 13.

Table 11: Effective impervious area for bioretention treatment

Catchment	Effective impervious area (ha)
B1	0.4795
B2	0.6169
B3	0.6654
B4	0.5032
B5	1.1852
B6	3.4368
B7	1.6834
B8	1.4105
B9	0
B10	1.2494
B11	1.4414
B12	1.3165
B13	1.6782
B14	0
B15	1.0448
B16	1.5614
B17	1.3164
B18	1.6937

B19	0.9714
B20	6.1908
B21	3.3316
B22	2.0172
B23	0.9805
B24	4.126
B25	1.3691
B26	2.0428
B27	0.368
B28	1.392
B29	2.4005
B30	0
Total	**46.4726**

5.3.2. Major drainage system

The roadside pipe and pit network and swales will be sized to convey the 20% Annual Exceedance Probability (AEP) event. In larger events runoff may be conveyed within the road reserves, with a maximum depth of 0.2 m in the 1% AEP event.

Stormwater modelling was undertaken using XPSWMM software. Bioretention basins were sized for trapped and discharging catchments for storage and infiltration of the first 15 mm event. Trapped catchment basins were sized for storage and infiltration of up to the 1% AEP event.

The loss rates adopted for each land use type is detailed in Table 12. The infiltration rates adopted based on the infiltration testing results and are detailed in Table 13.

Table 12: Uniform Loss rates

	Drainage/ POS	School	Road reserve	Residential (R30-40) >300m2
Initial Loss (mm)	20	15	3	15
Absolute loss (mm)	2	3	1	3

5.4. Non-structural controls

Non-structural controls to improve stormwater quality includes vegetation to be incorporated into the drainage areas to help prevent erosion, maintain infiltration, restrict water scouring, and remove particulate and soluble pollutants. Native species will be selected based on their intended purpose, predominantly being for nutrient removal, and will be in accordance with the *Vegetation guidelines for stormwater biofilters in the south-west of Western Australia* (Monash University 2014). The landscape plans provide further vegetation details and are provided in Appendix E.

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5.5. Basin Sizing Modelling Results

The bioretention treatment and flood storage areas required within each catchment and is detailed in Table 13 below.

Table 13: Basin design details

Basin ID	Trapped or discharging	Basin shape	Adopted infiltration rate (m/day)	First 15 mm basin design				20% AEP basin design				1% AEP basin design			
				Side slopes	Total depth (m)	Volume (m3)	Top area (m2)	Side slopes	Total depth (m)	Volume (m3)	Top area (m2)	Side slopes	Total depth (m)	Volume (m3)	Top area (m2)
B1	Trapped	Square	3	1 in 3	0.3	50	190	1 in 6	0.5	190	830	1 in 6	1.2	946	1354
B2	Trapped	Square	0.75	1 in 3	0.3	76	282	1 in 6	0.52	360	1450	1 in 6	1.2	1554	2098
B3	Trapped	Square	5	1 in 3	0.3	50	190	1 in 6	0.54	191	680	1 in 6	1.2	785	1142
B4	Trapped	Square	5	1 in 3	0.3	43	164	1 in 6	0.54	148	550	1 in 6	1.2	633	950
B5	Discharging	Square	5	1 in 3	0.3	86	317								
B6	Discharging	Square	5	1 in 3	0.3	268	949	**Overtops into roadside drainage network**							
B7	Discharging	Square	5	1 in 3	0.3	131	475								
B8	Discharging	Square	5	1 in 3	0.3	107	392								
B9	Trapped Retained bushland	Existing	2.3	NA	0	0	0	NA	0	0	0	NA	0	0	0
B10	Discharging	Square	5	1 in 3	0.3	96	353								
B11	Discharging	Square	5	1 in 3	0.3	102	372	**Overtops into roadside drainage network**							
B12	Discharging	Square	5	1 in 3	0.3	102	372								
B13	Discharging	Swale	5	1 in 3	0.3	131	475								
B14	Trapped	Existing	1	NA	0	0	0	NA	0	0	0	NA	0.39	2565	7000
B15	Trapped and discharging	Square	5	1 in 3	0.3	67	250	1 in 6	0.6	334	999				
B16	Trapped	Square	5	1 in 3	0.3	76	282	1 in 6	0.48	328	1540	1 in 6	1.2	1703	2285
B17	Trapped and discharging	Square	5	1 in 3	0.3	76	282	1 in 6	0.6	380	1129				

Basin ID	Trapped or discharging	Basin shape	Adopted infiltration rate (m/day)	First 15 mm basin design				20% AEP basin design				1% AEP basin design			
				Side slopes	Total depth (m)	Volume (m3)	Top area (m2)	Side slopes	Total depth (m)	Volume (m3)	Top area (m2)	Side slopes	Total depth (m)	Volume (m3)	Top area (m2)
B18	Discharging	Square	5	1 in 3	0.3	119	433	Overtops into roadside drainage network							
B19	Discharging	Square	5	1 in 3	0.3	76	282								
B20	Discharging	Swale	5	1 in 3	0.3	459	1607								
B21	Discharging	Square	5	1 in 3	0.3	268	949								
B22	Discharging	Swale	5	1 in 3	0.3	155	562								
B23	Discharging	Square	5	1 in 3	0.3	75	295								
B24	Trapped	Square	2.3	1 in 3	0.3	201	718	1 in 6	0.47	1114	5920	1 in 6	1.2	6028	7362
B25	Discharging	Square	5	1 in 3	0.3	102	372	Overtops into roadside drainage network							
B26	Discharging	Square	5	1 in 3	0.3	138	497								
B27	Discharging	Swale	5	1 in 3	0.3	34	134								
B28	Discharging	Swale	5	1 in 3	0.3	100	409								
B29	Trapped	Square	2.3	1 in 3	0.3	234	829	1 in 6	0.39	141	3390	1 in 6	1.2	3747	4597
B30	Trapped Retained bushland	Existing	0.75	NA	0	0	0	NA	0	0	0	NA	0.05	485	10000

5.6. Flood risk for trapped catchments with low clearance to groundwater

Pentium Water has undertaken an assessment of the flood risk presented in specific catchments of the development in a scenario where groundwater levels rise to the proposed Controlled Groundwater level (CGL) and no district scale groundwater pumping system has been implemented.

This trapped catchment assessment focused on stormwater basins which will have a clearance to CGL of less than 3 m and do not overtop into Lake Mariginiup or Little Mariginiup Lake include B4, B24, B14, B15, B16 and B17 (Figure 16). If groundwater levels were to rise, then the infiltration rates in these basins will be less than the design rates specified in Table 13.

If the infiltration rates in basins B24, B15, B16 and B17 was limited due to groundwater rise, then it is likely that in large storm events runoff will exceed the capacity of these basins and will be conveyed via the road reserves to B14 retained vegetation area, and potentially discharge over Pinjar Road into Da Vinci Park REW in large rainfall events.

If the infiltration rate in basin B4 was reduced, then it is likely that in large storm events runoff will overtop the basin and discharge over Coogee Road and into Lake Adams.

5.7. Cumulative Impacts to Lake Water Levels from other precincts

Pentium Water has undertaken an assessment of the cumulative flood risk presented to developments surrounding Lake Mariginiup based on the likely drainage catchment for the precincts across East Wanneroo. The drainage catchment for Lake Mariginiup was largely defined in the DWMS and the Little Mariginiup Lake and Lake Mariginiup catchment boundaries are presented in Figure 17. The majority of the site (Precinct 8) as well as external precinct areas drain into Lake Mariginiup.

The catchment areas, modelled flood depths and volumes within Lake Mariginiup and Little Mariginiup Lake are detailed in Table 14.

A cumulative assessment of all stormwater entering the lakes has been undertaken to determine the likely instantaneous lake level increase based on a significant rainfall event. The assessment revealed that a maximum flood depth in the 1% AEP event is 0.33 m and 0.63 m in Lake Mariginiup and Little Mariginiup Lake respectively. The assessment indicated that the cumulative impact or instantaneous lake water level rise in a 1% AEP rainfall event does not present a significant flood risk to the future development surrounding the lakes. This assessment is based on the current lake levels, the likely future lake water levels based on a controlled groundwater level, future lake water levels assuming wet future climate scenarios, and referencing the proposed earthworks level of Precinct 7 and 8.

Table 14: Lake Mariginiup and Little Mariginiup hydrology

			First 15 mm		20 % AEP (5 year) event		1% AEP (100 year) event	
Lake ID	Catchment area (ha)	Infiltration rate (m/day)	Max Depth (m)	Max Volume (m3)	Max Depth (m)	Max Volume (m3)	Max depth (m)	Max Volume (m3)
Lake Mariginiup	622	0	0.01	10,835	0.09	130,029	0.33	485,673
Little Mariginiup Lake	118	0	0.00	0	0.18	15,121	0.63	68,797

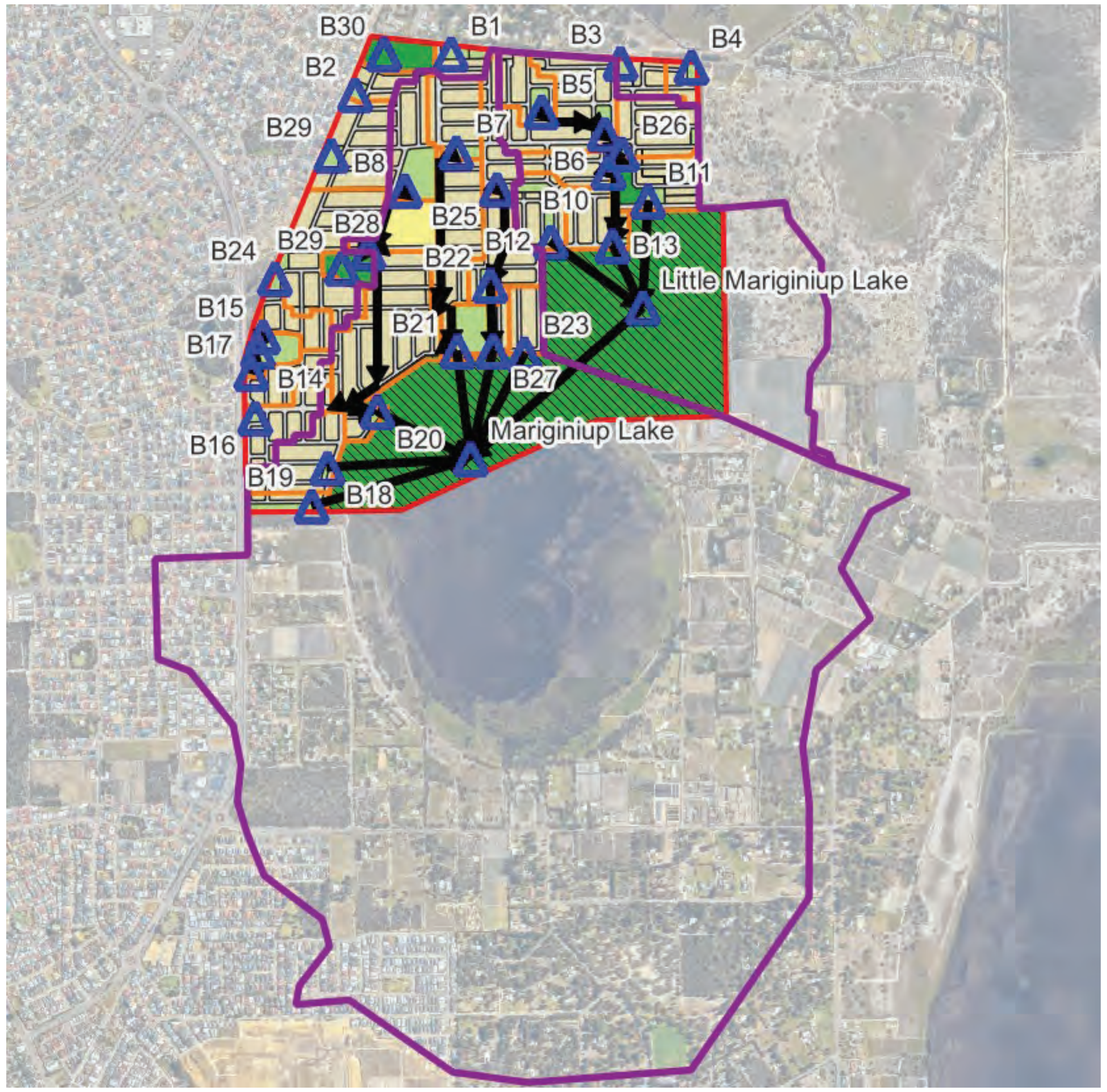

Figure 17: Lake Mariginiup and Little Mariginiup Lake Catchment boundaries (purple line)

6. Groundwater management

6.1. Overview

A district groundwater management scheme will control post-development groundwater level rise through subsoil drainage in areas that are likely to have shallow depth to groundwater. The groundwater management scheme is to be informed by a detailed groundwater model and concept engineering design that is currently under development. In the absence of the groundwater model results and the groundwater management scheme design, planning must follow requirements stipulated in the DWMS (Urbaqua, 2021).

6.2. Groundwater control

The DWMS proposed the CGL be represented by the 1986 to 1995 AAMGL, but notes:

> *The impacts of using an AAMGL rather than MGL (maximum groundwater level) as the CGL near wetlands and important environmental values will require further consideration when detailed modelling is undertaken for the preparation of the local water management strategy for each precinct.*

The DWMS also states:

> *Where local structure planning is proceeding in advance of the detailed local groundwater modelling being available, the local structure plan must:*
>
> - *Install groundwater management systems (subsoil drains) at invert levels based on the determined controlled groundwater level (CGL) in areas where the predicted future groundwater level is within 2m of the future*

The CGL and subsoil drainage extent have been assessed in accordance with the requirements specified in the DWMS.

6.2.1. Controlled Groundwater Level (CGL)

The proposed CGL for the East Wanneroo DSP area is considered appropriate for Precinct 8 without adjustment. The majority of the site has more than 5 m clearance to groundwater as presented in Figures 12 and 13.

Several surface water infiltration basins have been identified across the site. The DWMS specifies that subsoil drainage is to be at the CGL, and the subsoil drainage pipework will underlie the surface water infiltration basins where there is insufficient clearance to groundwater.

6.2.2. Subsoil requirements

Given the relatively large separation between the design surface and the proposed CGL, it is not anticipated that subsoil drainage is a significant design constraint for Precinct 8. However, subsoils may be installed beneath parts of the site with lower clearance to CGL as a contingency against rising groundwater levels.

6.3. Groundwater modelling

No specific groundwater modelling has been undertaken to provide groundwater level comparisons between “no-development” and “post-development” model scenarios as it is understood this work is being completed by DPLH. The proponent for Precinct 8 understands that modifications to the drainage design and earthworks design may be required following the upcoming Groundwater Management Scheme design process.

6.4. Groundwater management responses

It is understood that Precinct 8 is highly likely to not required subsoil drainage to control groundwater levels based on predicted groundwater level rise outputs from DPLH’s groundwater modelling considering land use change and future climate scenarios. However, should subsoil drainage be required then subsoil drains will be located beneath road

reserves and POS areas to aid infiltration. The detailed design of the subsoil drainage network has not yet been undertaken and will be confirmed with DPLH and their consultants assessing groundwater management.

The DWMS describes a groundwater management scheme that will be controlled by subsoil drainage. Precinct 8 is an undulating area with internal draining to two depression areas (Lake Mariginiup and Little Mariginiup Lake). The project team understands that these internally draining catchments will be governed by the groundwater harvesting scheme and associated lake water level controls.

The current earthworks design and drainage design allows for catchments to drain to low points in the landscape (primarily the lakes) where it is anticipated a pumping system will abstraction or transfer stormwater to a disposal or final use location.

The current urban design and engineering drainage design supports flexibility in response to the future groundwater management scheme and is consistent with the known design principles. The urban design responds to the likely infrastructure demands and land take of the groundwater management scheme.

7. Monitoring requirements

7.1. Pre-development monitoring

The pre-development monitoring has been completed across the Precinct 8 development. Details are provided in Section 2.11.3 and 2.11.4.

7.2. Post-development monitoring

It is understood that the Develop Contribution Plan will fund the district scale water level and quality monitoring program as was specified in the DWMS. However, it is still anticipated that local scale water monitoring will be required. Once the district scale plan is published and understand, the post-development monitoring commitments can be better defined in future Urban Water Management Plans UWMPs. In the interim, the stand-alone post-development monitoring commitments are identified below.

Post-development monitoring will be carried out at the site to detect changes to water quality and verify the performance of the proposed management strategies. The proposed period for post-development monitoring is no less than 3 years following practical completion, as outlined in the DWMS (Urbaqua, 2021). Additional monitoring may be required at the site and should be confirmed with DWER.

Post-development groundwater quality and level monitoring will occur from eight bores. Bores that were monitored pre-development will attempt to be located for post-development monitoring. Where bores have been either destroyed or are no longer available for use, a new bore is to be installed in a location as close as possible to the original bore to ensure consistency in the monitoring regime.

Groundwater quality monitoring will occur on a quarterly basis. Groundwater samples will be analysed for the same parameters as predevelopment.

Groundwater level monitoring will occur monthly during winter (June to October) and quarterly during the rest of the year.

Surface water level and quality monitoring will be undertaken within Lake Mariginiup at two locations, and within Little Mariginiup Lake at one location from the site on a quarterly basis. Surface water samples will be analysed for the same parameters as predevelopment.

7.3. Trigger values

Groundwater and surface water Total Nitrogen (TN) and Total Phosphorus (TP) water quality monitoring results will be compared to the baseline values obtained from the pre-development monitoring.

Groundwater trigger values are detailed in Table 12 and were calculate as the predevelopment average plus 20%.

Surace water trigger values are detailed in Table 13. The surface water TN trigger value was calculated as the predevelopment average plus 20%, and the TP trigger value adopted is the ANZECC guideline (ANZECC 2000) value.

If TN or TP in groundwater or surface water samples exceed the trigger values for two consecutive sampling occasions, contingency measures identified below shall be employed. Consideration will be given to the source of the potential water quality exceedances to determine whether the exceedance is site specific or originating from outside the site.

Table 15: Post development groundwater quality trigger values

Bore ID	Total Nitrogen		Total Phosphorus	
	Predevelopment Average (mg/L)	Trigger	Predevelopment Average (mg/L)	Trigger
ANZECC guideline values	*1.2*		*0.065*	
Short-term HRAP target concentrations	*2.0*		*0.2*	
Long-term HRAP target concentrations	*1.0*		*0.1*	
MB01	18	21.6	4.225	5.07
MB02	18.35	22.02	0.695	0.834
MB03	1.95	2.34	0.185	0.222
MB04	4.65	5.58	0.875	1.05
MB05	53.3	63.96	0.76	0.912
MB06	31.8	38.16	0.915	1.098
MB07	4.55	5.46	0.445	0.534

Table 16: Post-development surface water quality trigger values

Parameter	ANZECC (2000) guideline	Predevelopment Average	Trigger
TN (mg/L)	*1.5*	5.72	6.864
TP (mg/L)	*0.05*	0.03	0.05

7.4. Contingency measures

In the event post-development data exceeds trigger values by at least 20% on two consecutive occasions, an immediate re-sampling will be undertaken to verify the exceedance. If this confirms a deterioration in water quality then an investigation will be undertaken to establish the likely cause of the exceedances, the most likely impacts, and available remedies.

The primary contingency measure available in the event of deterioration in water quality will include assessment of whether the pollution is a point or diffuse source. This will require an investigation into the location of the contamination and an assessment of whether the pollution is due to the development or an external factor. At that point, a specific contingency plan will be implemented, which may include:

- Removal of the pollution
- Assessment into the functionality of the drainage system and bio-infiltration areas
- Further soil amendment in infiltration / treatment areas
- Increased planting of nutrient stripping vegetation in infiltration areas
- Review of drainage maintenance plans to ensure correct practices are being implemented
- Increased public awareness and education programs
- Increased monitoring program including monitoring up-gradient of the site to determine potential off-site nutrient sources.

7.5. Reporting

Annual reporting is proposed to review the post-development monitoring program and recommend revisions where necessary to improve understanding of surface water and groundwater systems.

The results obtained from post-development monitoring will be compared to pre-development monitoring data and ANZECC guidelines (ANZECC, 2000) and submitted annually to the City. The report will outline and impact the development has had on the hydrological conditions and water quality and present necessary contingency measures where required.

8. Further investigations

8.1. Further work

The preparation of Urban Water Management Plans (UWMPs) will be required as a condition of subdivision approval and will include the following design measures in more detail:

- Compliance with this LWMS criteria and objectives to the satisfaction of the City and DWER
- Detailed stormwater drainage design including final levels and dimensions for bioretention and flood storage areas
- Specific detailed information on structural and non-structural Best Management Practices to be implemented within each subdivision
- Final subdivision layout including final cut and fill levels, minor and major drainage layout, and overland flow paths
- Management of subdivision works including details of licence application for dewatering or dust suppression if required
- Updated POS landscaping design drawings which will include design contours, cross-sections, storage areas, plant species, fertiliser regimes and irrigation scheduling
- Detailed monitoring program for both groundwater and surface water monitoring including sampling locations
- Finalised implementation plan including roles and responsibilities of all parties involved.

8.2. Implementation plan

The proposed operation and maintenance program is outlined in Table 17 below.

Table 17: LWMS roles and responsibilities

Principle	Role	Responsibility	Timescale
Monitoring	Groundwater monitoring	The proponent	Quarterly groundwater levels and water quality monitoring of bores for a period of 3 years following practical completion, with a review after 18 months.
	Surface water monitoring	The proponent	Quarterly surface water levels and water quality monitoring for a period of 3 years following practical completion, with a review after 18 months.
Irrigation bore	Bore monitoring and maintenance	The proponent until POS handover. Bore to be serviced prior to pump handover to the City.	As per the bore licence conditions specified by DWER until handover to the City.
Subdivision management	Construction and site works management	The proponent	As required during construction until handover to the City.
	Waste and pollution management	The proponent	As required during construction until handover to the City.
	Erosion Control	The proponent	As required during construction.

Principle	Role	Responsibility	Timescale
POS and landscaped community areas	Maintenance of drainage infrastructure	The proponent	As specified within the POS design documentation until handover to City.
	Fertiliser application	The proponent	As specified within the POS design documentation until handover to City.
	Irrigation systems	The proponent	As specified within the POS design documentation until handover to City.

9. References

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Appendix A: Local Structure Plan

Rowe Group, 2023

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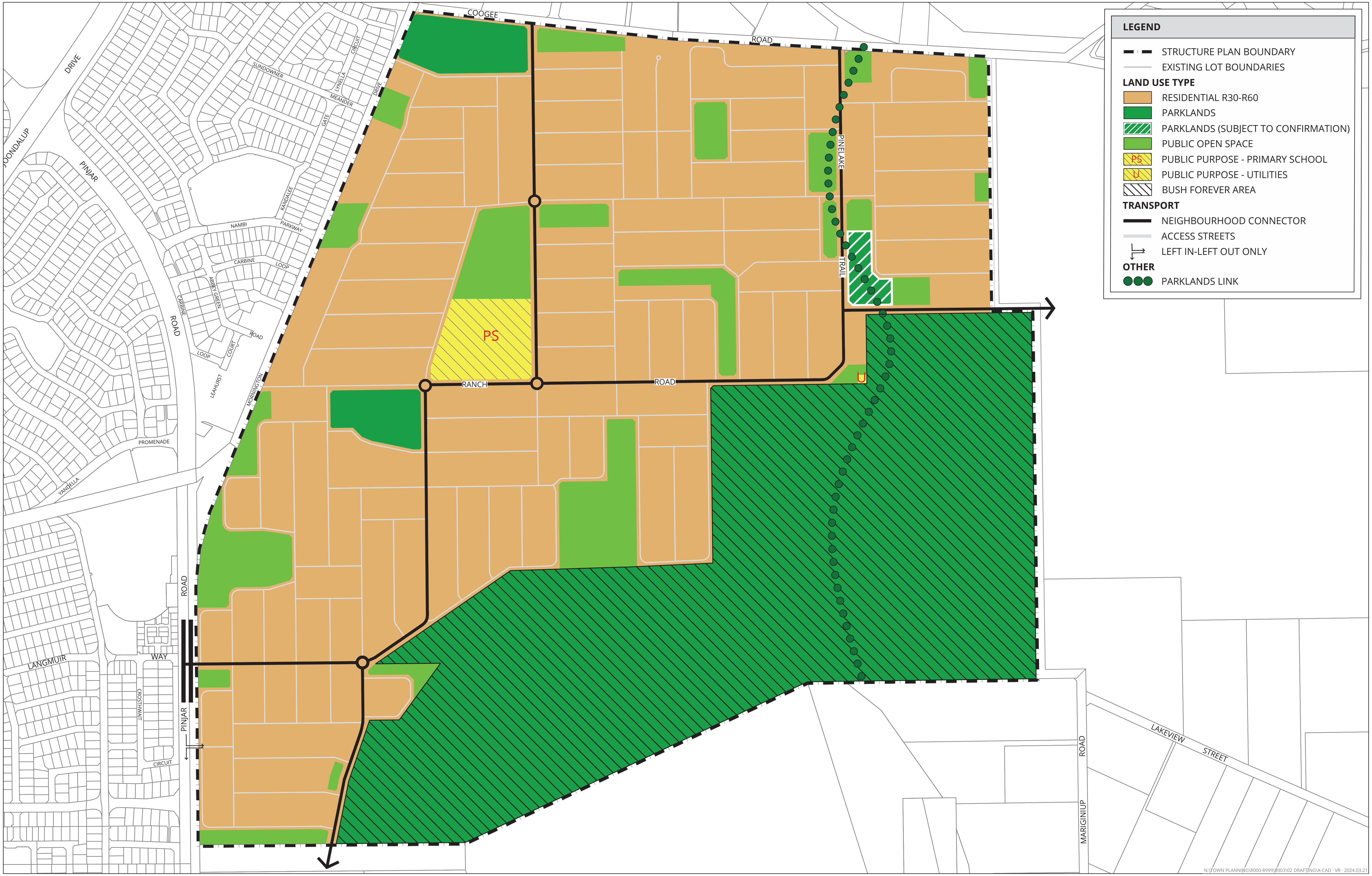

PLAN 1 - LOCAL STRUCTURE PLAN

PRECINCT 8 - RANCH ROAD

EAST WANNEROO

DRAFT

0 180 m

SCALE @ A3: 1:7500

8903-LSP-01-G

DRAWN: VR
DATE CREATED: 2024.03.21
PROJECTION: MGA50 GDA2020
CADASTRE: LANDGATE

FIGURE 15

INDICATIVE SUBDIVISION CONCEPT

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Appendix B: Infiltrating testing report

Galt, 2023

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TECHNICAL MEMORANDUM

WAE221033-02 002 TM Rev0 | 31 October 2023

To: Rod Gardiner | e-mail: rod@qubeproperty.com.au

From: Rick Piovesan | Sender's email: rick.piovesan@galtgeo.com.au

INFILTRATION TESTING
PROPOSED DRAINAGE SWALES
PRECINCT 8, EAST WANNEROO, MARIGINIUP

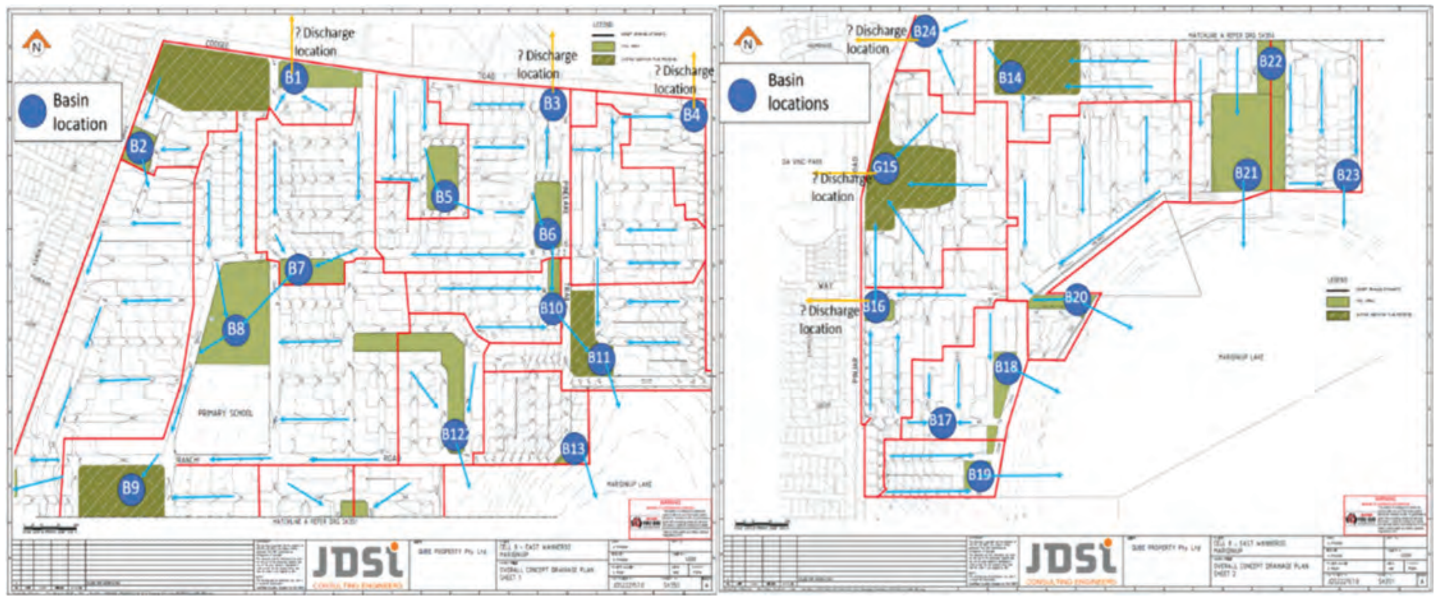
Dear Rod,

1. INTRODUCTION

This technical memorandum presents the outcomes of Galt Geotechnics' (Galt's) infiltration testing at 11 proposed swale locations across Precinct 8 of the East Wanneroo development located in Mariginiup. The locations of the test sites are shown in Figure 1, Site and Location Plan.

2. BACKGROUND

We understand that QUBE is managing the Local Structure Plan on behalf of a number of owners at Precinct 8 of the East Wanneroo development. Pentium Water is preparing the Local Water Management Strategy for the Local Structure Plan. The preliminary basin layouts are shown below:



Infiltration testing and soil profiling was required at the following proposed swale locations:

- B2
- B4
- B6
- B7
- B10
- B12
- B13
- G15
- B16
- B21
- B24

3. PROJECT OBJECTIVES

The objectives of the study were to:

- assess subsurface soil and groundwater conditions at the swale locations; and
- assess the permeability of the soils at each swale for potential on-site disposal of stormwater by infiltration.

4. FIELDWORK

Fieldwork was carried out on 3 and 4 October 2023 and comprised:

- drilling of 22 machine auger boreholes extending to a target depth of 3 m, in each instance, and
- infiltration tests using the 'inverse auger hole' technique in each borehole, at depths typically ranging from about 2.75 m to 2.9 m below ground (two tests carried out at a depth of around 1 m due to shallow groundwater).

General

Geotechnical engineers from Galt located the test positions, conducted the drilling, logged the materials encountered in the boreholes and performed infiltration testing. The approximate test locations are shown on Figure 1, Site and Location Plan. Site Photographs are presented in Attachment A, Site Photographs.

Boreholes

Machine auger boreholes were drilled using a utility mounted drill rig ("EVH Scout 1750") equipped with a 90 mm diameter solid auger. The drill rig was supplied and operated by Galt. Summary borehole reports and photographs of the spoil at each infiltration test location are presented in Attachment B.

Infiltration Testing

Infiltration testing was carried out using the method described by Cocks[1]. Measurements were recorded using a 'Rugged Troll' pressure sensor. The results of the infiltration testing are presented in Attachment C, Infiltration Test Results. A summary of the results is presented in Table 1: Summary of Infiltration Test Results, along with the depth at which the tests were conducted.

[1] Cocks, G (2007), "Disposal of Stormwater Runoff by Soakage in Perth Western Australia", Journal and News of the Australian Geomechanics Society, Volume 42 No. 3, pp 101-114

Table 1: Summary of Infiltration Test Results

Test Number	Swale Location	Soil Profile	Depth of Test Below Existing Surface (m)	Minimum Unsaturated Hydraulic Conductivity, k (m/day)
IT01	B2	SAND	2.8	0.7
IT02			2.8	0.8
IT03	B6		2.8	3.0
IT04			2.8	7.9
IT05	B4		2.9	>15
IT06			2.75	2.4
IT07	B7		2.9	1.0
IT08			2.75	>15
IT09	B10		2.8	>15
IT10			2.8	1.1
IT11	B12		2.75	>15
IT12			2.9	4.5
IT13	B13		2.8	12.7
IT14			2.8	5.9
IT15	G15		1.0	14.3
IT16			1.45	5.1
IT17	B16		2.8	5.1
IT18			2.8	12.5
IT19	B21		2.7	14.6
IT20			2.8	7.1
IT21	B24		2.9	3.9
IT22			2.9	0.7

Notes:
1. All boreholes drilled to target depth of 3 m
2. IT15 and IT16 carried out at 1.0 m and 1.45 m respectively due to groundwater at 1.5 m depth. Groundwater was not encountered at other test locations.

As shown in Table 1, the results of the infiltration testing varied from 0.7 m/day to >15 m/day.

Significant variations in the minimum hydraulic conductivity were recorded B4, B7, B10 and B24.

We did not observe any obvious reasons for the lower permeabilities recorded at test locations as similar subsurface soils were encountered at most test locations.

5. CLOSURE

We draw your attention to Attachment D of this memorandum, "Understanding your Report". The information provided within is intended to inform you as to what your realistic expectations of this report should be. Guidance is also provided on how to minimize risks associated with groundworks for this project. This information is provided not to reduce the level of responsibility accepted by Galt, but to ensure that all parties who rely on this report are aware of the responsibilities each assumes in so doing.

Please advise if you require anything further at this stage.

GALT GEOTECHNICS

Rick Piovesan CPEng

Geotechnical Engineer

Attachments: Figure 1 – Site and Location Plan
A – Site Photographs
B – Summary Borehole Reports
C – Infiltration Test Results
D - Understanding your Report

https://galtgeo.sharepoint.com/sites/WAE221033/Shared Documents/02 Qube Infilt Testing/03 Correspondence/WAE221033-02 002 TM Rev0.docx

FIGURE

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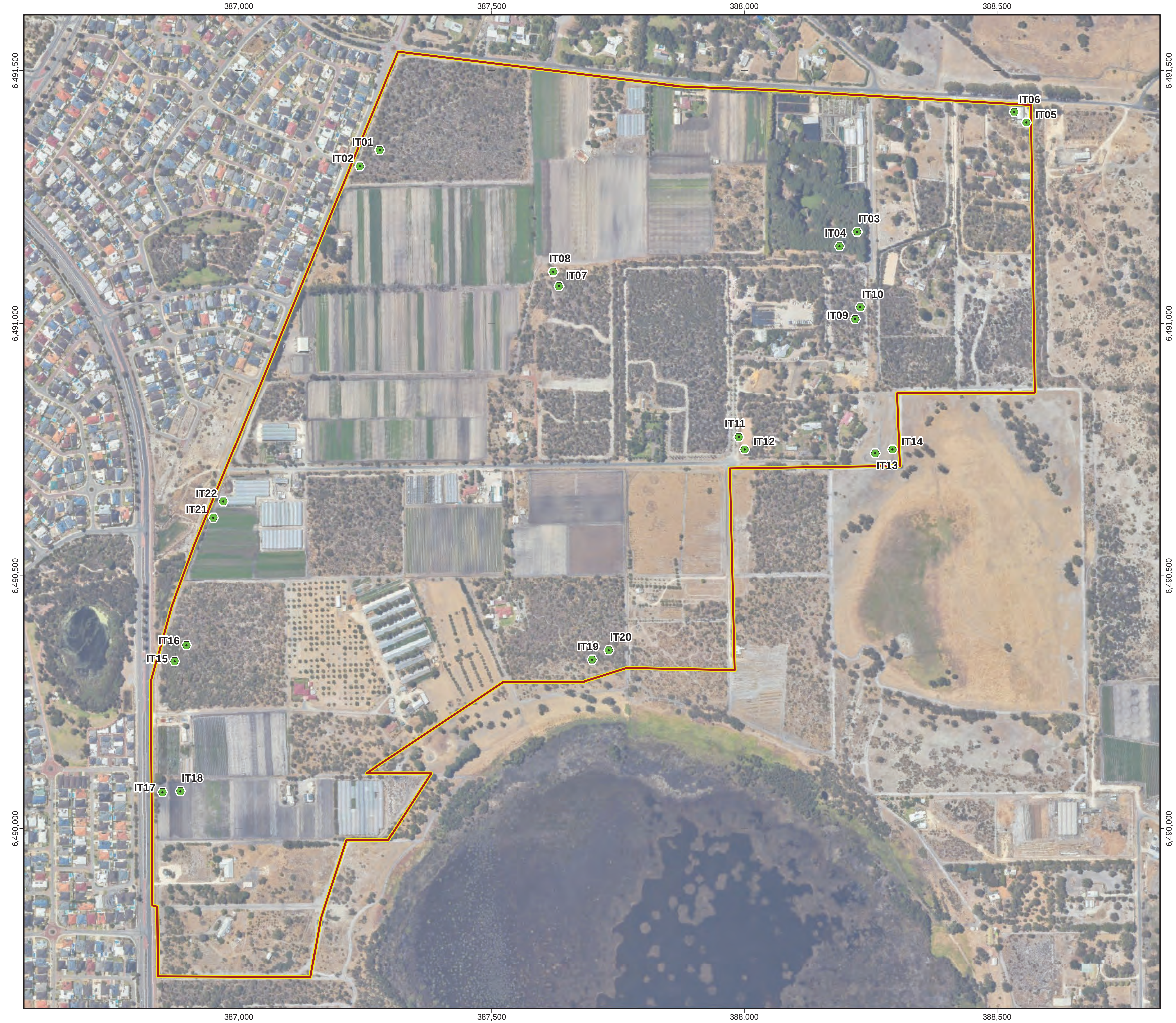
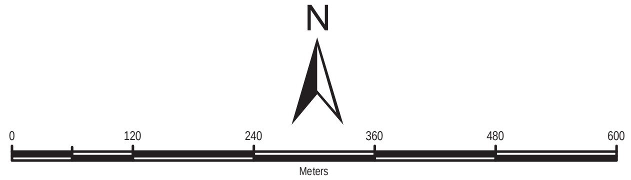


Legend

- Site Boundary
- Infiltration Test



NOTES

Aerial Imagery and Cadastre sourced from Landgate/SLIP

SCALE	1:7,500 (A3)
DRAWN	DAC
DATE DRAWN	27/10/2023
CHECKED	_
DATE CHECKED	_
PROJECTION	GDA 1994 MGA Zone 50

Galt Environmental Pty Ltd
ACN : 161 708 998
Tel : +61 (0)8 6272-0200
Address: 50 Edward Street
Osborne Park WA 6017

SITE	PRECINCT8 MARIGINIUP
LOCATION	PRECINCT8 - MARIGINIUP EAST WANNEROO
TITLE	SITE & LOCATION PLAN
Job No	WAE221033-02
Fig No	FIGURE 1
Rev	A

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ATTACHMENT A

Site Photographs

Photograph 1: Drill rig set up near IT06

Photograph 2: View of site near IT06

Photograph 3: Drill rig set up at IT07

Photograph 4: Typical spoil (borehole at IT03)

Photograph 5: Drilling borehole near IT07

Photograph 6: Typical view from near test location IT09

Photograph 7: Standpipe within IT09 to carry out infiltration test

Photograph 8: View of site near IT14

Photograph 9: View of site near IT22

Photograph 10: View of site near IT18

ATTACHMENT B

Summary Borehole Reports

SUMMARY MACHINE AUGER BOREHOLE LOGS

Job Number: WAE221033-02
Client: QUBE Property Group
Project: Precinct 8, East Wanneroo Development
Location: Mariginiup
Date Performed: 3-4 October 2023
Logged By: MDS/KS

Borehole IT01

Test Depth (m)	Stratigraphy
0.0 – 0.2	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey becoming pale yellow, trace fines
0.2 – 3.0	pale yellow becoming yellow with depth.
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT02

Test Depth (m)	Stratigraphy
0.0 – 0.3	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey becoming pale yellow, trace fines
0.3 – 3.0	pale yellow becoming yellow with depth.
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT03

Test Depth (m)	Stratigraphy
0.0 – 0.2	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey, trace fines
0.2 – 3.0	pale grey/pale yellow becoming yellow with depth.
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT04

Test Depth (m)	Stratigraphy
0.0 – 0.3	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey, trace fines
0.3 – 3.0	pale yellow becoming yellow with depth.
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

SUMMARY MACHINE AUGER BOREHOLE LOGS

Borehole IT05

Test Depth (m)	Stratigraphy
0.0 – 3.0	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, pale grey, trace fines
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT06

Test Depth (m)	Stratigraphy
0.0 – 3.0	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, pale grey, trace fines
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

SUMMARY MACHINE AUGER
BOREHOLE LOGS

Borehole IT07

Test Depth (m)	Stratigraphy
0.0 – 0.3	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, pale grey, trace fines
0.3 – 3.0	pale yellow becoming yellow with depth.
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT08

Test Depth (m)	Stratigraphy
0.0 – 0.4	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey, trace fines
0.4 – 3.0	pale yellow becoming yellow with depth.
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT09

Test Depth (m)	Stratigraphy
0.0 – 3.0	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, pale yellow becoming yellow with depth, trace fines
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT10

Test Depth (m)	Stratigraphy
0.0 – 3.0	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, pale yellow becoming yellow with depth, trace fines
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

SUMMARY MACHINE AUGER BOREHOLE LOGS

Borehole IT11

Test Depth (m)	Stratigraphy
0.0 – 0.3	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, pale yellow, trace fines, trace gravels
0.3 – 3.0	grey becoming yellow with depth, no gravels.
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT12

Test Depth (m)	Stratigraphy
0.0 – 0.5	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, dark brown-grey, trace fines
0.5 – 0.8	pale brown
0.8 – 3.0	yellow
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT13

Test Depth (m)	Stratigraphy
0.0 – 0.9	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey becoming pale grey, trace fines
0.9 – 3.0	pale grey to off-white
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT14

Test Depth (m)	Stratigraphy
0.0 – 0.9	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey becoming pale grey, trace fines
0.9 – 3.0	pale grey to off-white
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT15

Test Depth (m)	Stratigraphy
0.0 – 0.9	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey becoming pale grey, trace fines
0.9 – 3.0	brown
Hole terminated at 3.0 m Target Depth Groundwater encountered at 1.5 m	

Borehole IT16

Test Depth (m)	Stratigraphy
0.0 – 1.3	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey becoming pale grey, trace fines
1.3 – 3.0	brown
Hole terminated at 2.0 m Target Depth Groundwater encountered at 1.5 m	

SUMMARY MACHINE AUGER BOREHOLE LOGS

Borehole IT17

Test Depth (m)	Stratigraphy
0.0 – 1.2	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey becoming pale grey, trace fines
1.2 – 3.0	pale grey to off-white
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT18

Test Depth (m)	Stratigraphy
0.0 – 0.8	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey becoming pale grey, trace fines
0.8 – 3.0	pale grey to off-white
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT19

Test Depth (m)	Stratigraphy
0.0 – 3.0	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey to off-white, trace fines
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT20

Test Depth (m)	Stratigraphy
0.0 – 3.0	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey to off-white, trace fines
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

Borehole IT21

Test Depth (m)	Stratigraphy
0.0 – 1.5	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey becoming pale grey, trace fines
1.5 – 3.0	pale grey to off-white
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

SUMMARY MACHINE AUGER BOREHOLE LOGS

Borehole IT22

Test Depth (m)	Stratigraphy
0.0 – 1.1	SAND (SP), fine to coarse grained, sub-angular to sub-rounded, grey becoming pale grey, trace fines
1.1 – 3.0	pale grey to off-white
Hole terminated at 3.0 m Target Depth Groundwater not encountered.	

ATTACHMENT C

Infiltration Test Results

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

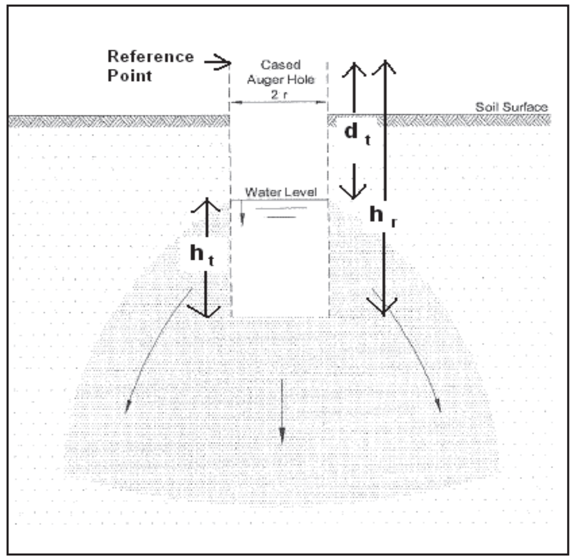
Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT01
Test Depth:	2.80 m

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

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Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

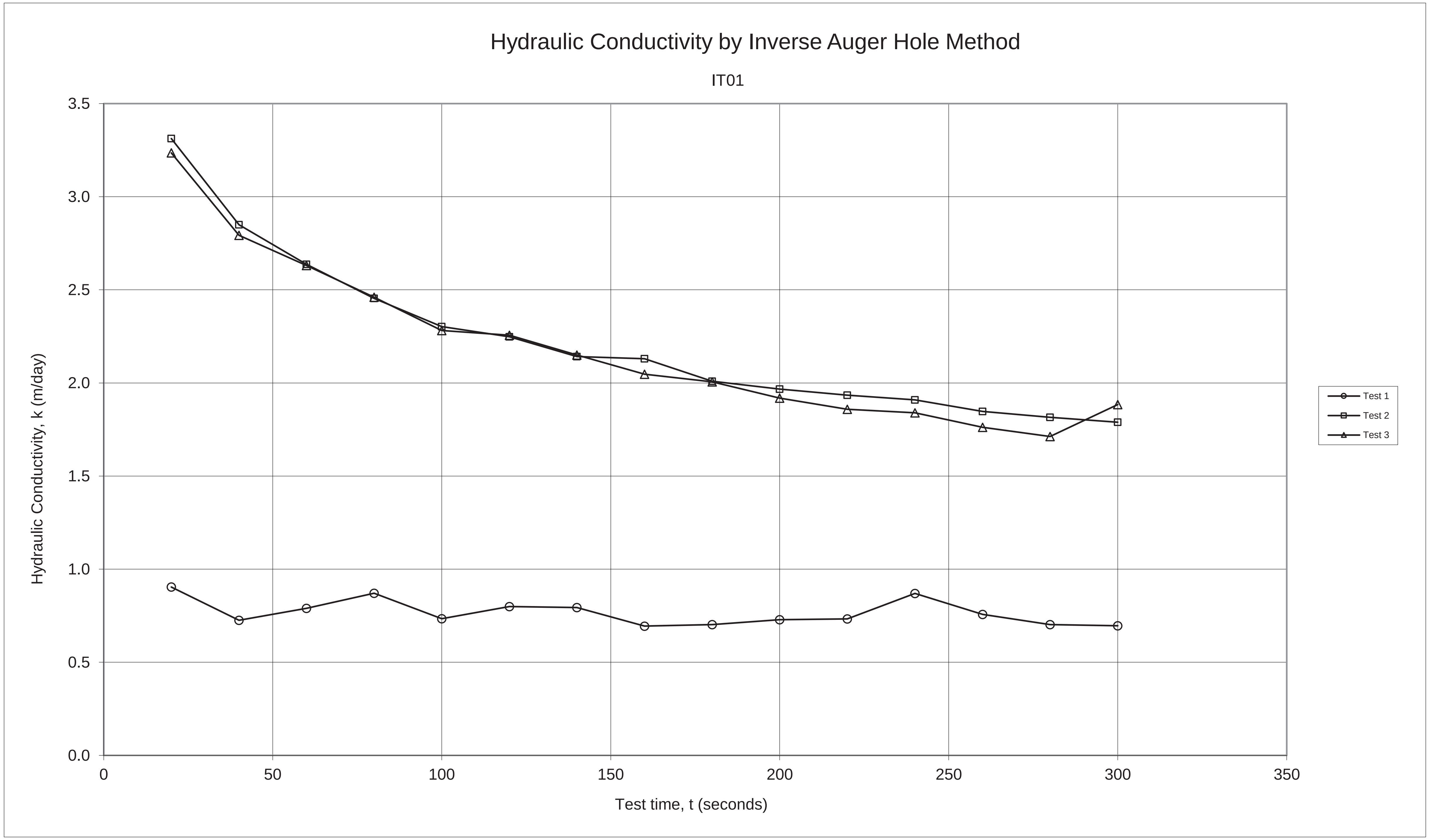
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.283	0.517		
20	2.288	0.512	1.0E-05	0.9
40	2.291	0.509	8.4E-06	0.7
60	2.296	0.504	9.1E-06	0.8
80	2.302	0.498	1.0E-05	0.9
100	2.303	0.497	8.5E-06	0.7
120	2.309	0.491	9.3E-06	0.8
140	2.313	0.487	9.2E-06	0.8
160	2.313	0.487	8.0E-06	0.7
180	2.317	0.483	8.1E-06	0.7
200	2.322	0.478	8.4E-06	0.7
220	2.326	0.474	8.5E-06	0.7
240	2.338	0.462	1.0E-05	0.9
260	2.335	0.465	8.8E-06	0.8
280	2.335	0.465	8.1E-06	0.7
300	2.338	0.462	8.1E-06	0.7
		AVERAGE	8.9E-06	0.8

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.928	0.872		
20	1.958	0.842	3.8E-05	3.3
40	1.979	0.821	3.3E-05	2.8
60	1.998	0.802	3.1E-05	2.6
80	2.014	0.786	2.8E-05	2.5
100	2.028	0.772	2.7E-05	2.3
120	2.044	0.756	2.6E-05	2.2
140	2.056	0.744	2.5E-05	2.1
160	2.072	0.728	2.5E-05	2.1
180	2.08	0.72	2.3E-05	2.0
200	2.092	0.708	2.3E-05	2.0
220	2.104	0.696	2.2E-05	1.9
240	2.116	0.684	2.2E-05	1.9
260	2.124	0.676	2.1E-05	1.8
280	2.134	0.666	2.1E-05	1.8
300	2.144	0.656	2.1E-05	1.8
		AVERAGE	2.6E-05	2.2

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.785	1.015		
20	1.819	0.981	3.7E-05	3.2
40	1.843	0.957	3.2E-05	2.8
60	1.866	0.934	3.0E-05	2.6
80	1.885	0.915	2.8E-05	2.5
100	1.9	0.9	2.6E-05	2.3
120	1.92	0.88	2.6E-05	2.3
140	1.934	0.866	2.5E-05	2.2
160	1.946	0.854	2.4E-05	2.0
180	1.961	0.839	2.3E-05	2.0
200	1.971	0.829	2.2E-05	1.9
220	1.982	0.818	2.2E-05	1.9
240	1.996	0.804	2.1E-05	1.8
260	2.003	0.797	2.0E-05	1.8
280	2.012	0.788	2.0E-05	1.7
300	2.047	0.753	2.2E-05	1.9
		AVERAGE	2.5E-05	2.2



https://galtgeo.sharepoint.com/sites/WAE221033/Shared Documents/02 Qube Infilt Testing/08 Analysis/20231006 - Permeability Inverse Auger Spreadsheets MDS-KS/WAE221033-02 IT Results Combined

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

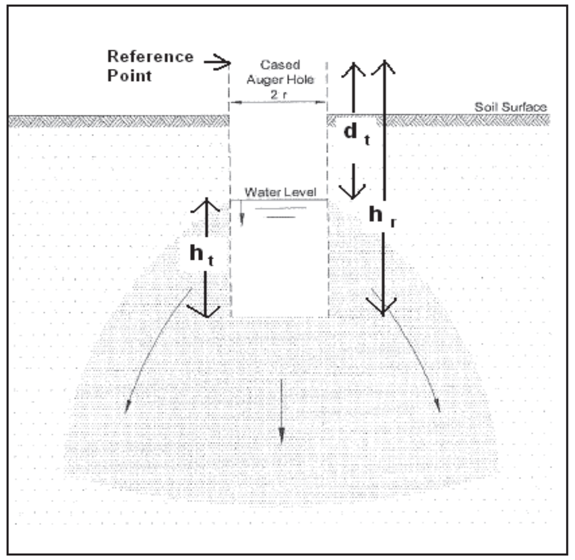
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT02
Test Depth:	2.80 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

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(green)	Calculated field
(orange)	Comment field
(crossed)	Field not used
(yellow)	Fixed field

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

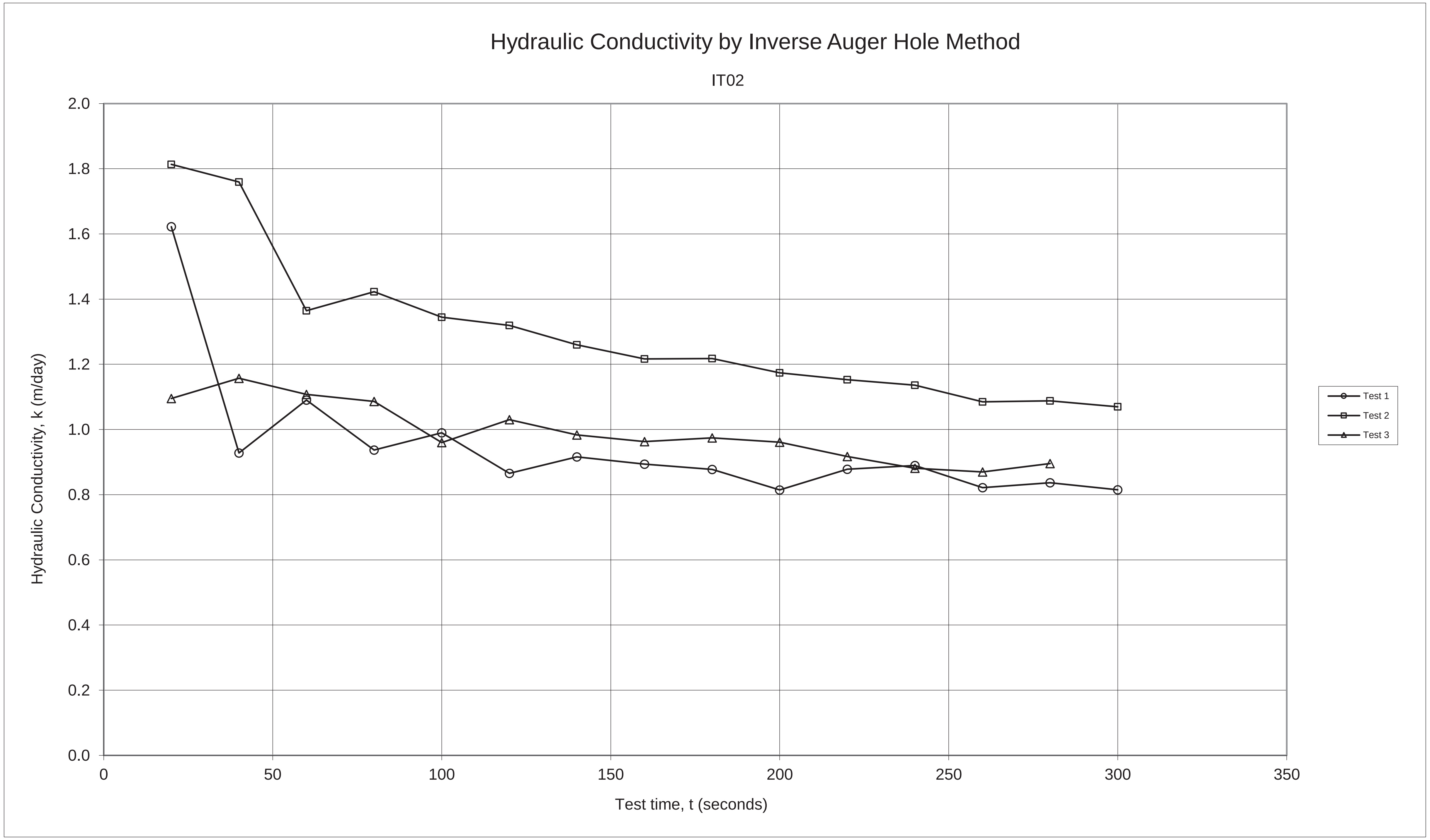
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.4	0.4		
20	2.407	0.393	1.9E-05	1.6
40	2.408	0.392	1.1E-05	0.9
60	2.414	0.386	1.3E-05	1.1
80	2.416	0.384	1.1E-05	0.9
100	2.421	0.379	1.1E-05	1.0
120	2.422	0.378	1.0E-05	0.9
140	2.427	0.373	1.1E-05	0.9
160	2.43	0.37	1.0E-05	0.9
180	2.433	0.367	1.0E-05	0.9
200	2.434	0.366	9.4E-06	0.8
220	2.44	0.36	1.0E-05	0.9
240	2.444	0.356	1.0E-05	0.9
260	2.444	0.356	9.5E-06	0.8
280	2.448	0.352	9.7E-06	0.8
300	2.45	0.35	9.4E-06	0.8
		AVERAGE	1.1E-05	0.9

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.12	0.68		
20	2.133	0.667	2.1E-05	1.8
40	2.145	0.655	2.0E-05	1.8
60	2.149	0.651	1.6E-05	1.4
80	2.16	0.64	1.6E-05	1.4
100	2.167	0.633	1.6E-05	1.3
120	2.175	0.625	1.5E-05	1.3
140	2.181	0.619	1.5E-05	1.3
160	2.187	0.613	1.4E-05	1.2
180	2.195	0.605	1.4E-05	1.2
200	2.2	0.6	1.4E-05	1.2
220	2.206	0.594	1.3E-05	1.2
240	2.212	0.588	1.3E-05	1.1
260	2.215	0.585	1.3E-05	1.1
280	2.222	0.578	1.3E-05	1.1
300	2.227	0.573	1.2E-05	1.1
		AVERAGE	1.5E-05	1.3

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.931	0.869		
20	1.941	0.859	1.3E-05	1.1
40	1.952	0.848	1.3E-05	1.2
60	1.961	0.839	1.3E-05	1.1
80	1.97	0.83	1.3E-05	1.1
100	1.974	0.826	1.1E-05	1.0
120	1.986	0.814	1.2E-05	1.0
140	1.992	0.808	1.1E-05	1.0
160	1.999	0.801	1.1E-05	1.0
180	2.008	0.792	1.1E-05	1.0
200	2.015	0.785	1.1E-05	1.0
220	2.019	0.781	1.1E-05	0.9
240	2.023	0.777	1.0E-05	0.9
260	2.029	0.771	1.0E-05	0.9
280	2.039	0.761	1.0E-05	0.9
		AVERAGE	1.1E-05	1.0


Hydraulic Conductivity by Inverse Auger Hole Method
IT02
Hydraulic Conductivity, k (m/day)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
350
Test time, t (seconds)
Test 1
Test 2
Test 3

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

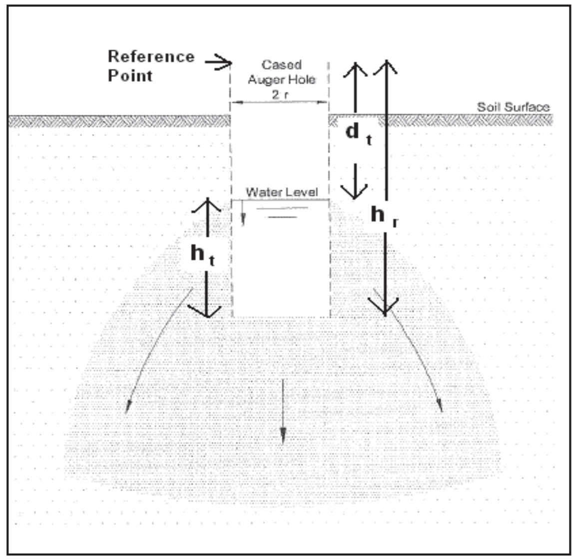
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT03
Test Depth:	2.80 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



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Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

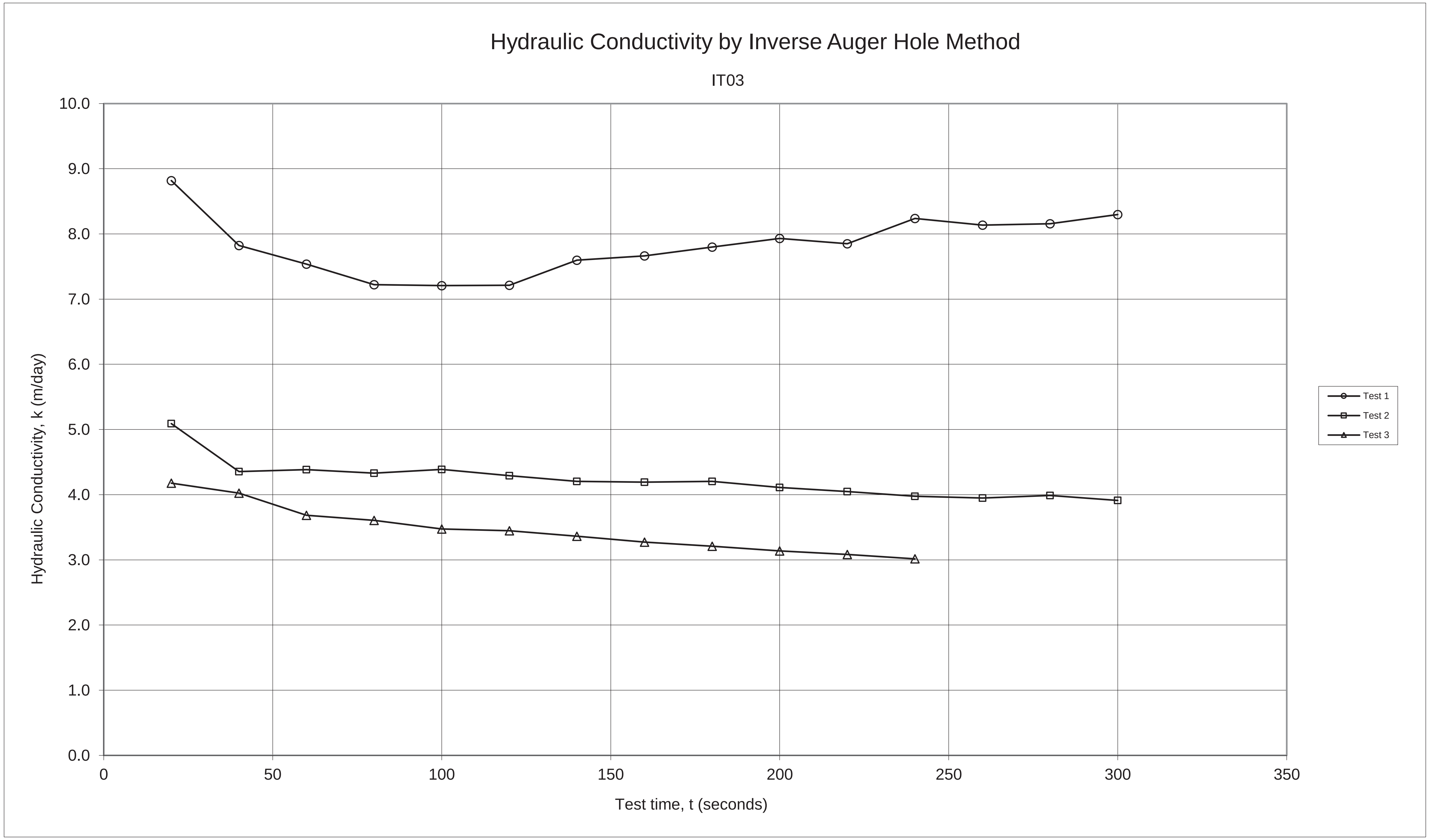
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.5	0.3		
20	2.528	0.272	1.0E-04	8.8
40	2.548	0.252	9.1E-05	7.8
60	2.567	0.233	8.7E-05	7.5
80	2.583	0.217	8.4E-05	7.2
100	2.6	0.2	8.3E-05	7.2
120	2.616	0.184	8.3E-05	7.2
140	2.636	0.164	8.8E-05	7.6
160	2.651	0.149	8.9E-05	7.7
180	2.666	0.134	9.0E-05	7.8
200	2.68	0.12	9.2E-05	7.9
220	2.69	0.11	9.1E-05	7.9
240	2.706	0.094	9.5E-05	8.2
260	2.714	0.086	9.4E-05	8.1
280	2.723	0.077	9.4E-05	8.2
300	2.733	0.067	9.6E-05	8.3
		AVERAGE	9.1E-05	7.8

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.333	0.467		
20	2.358	0.442	5.9E-05	5.1
40	2.375	0.425	5.0E-05	4.4
60	2.395	0.405	5.1E-05	4.4
80	2.413	0.387	5.0E-05	4.3
100	2.432	0.368	5.1E-05	4.4
120	2.447	0.353	5.0E-05	4.3
140	2.461	0.339	4.9E-05	4.2
160	2.476	0.324	4.9E-05	4.2
180	2.491	0.309	4.9E-05	4.2
200	2.502	0.298	4.8E-05	4.1
220	2.513	0.287	4.7E-05	4.0
240	2.523	0.277	4.6E-05	4.0
260	2.534	0.266	4.6E-05	3.9
280	2.547	0.253	4.6E-05	4.0
300	2.555	0.245	4.5E-05	3.9
		AVERAGE	4.9E-05	4.2

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.395	0.405		
20	2.413	0.387	4.8E-05	4.2
40	2.429	0.371	4.7E-05	4.0
60	2.441	0.359	4.3E-05	3.7
80	2.454	0.346	4.2E-05	3.6
100	2.465	0.335	4.0E-05	3.5
120	2.477	0.323	4.0E-05	3.4
140	2.487	0.313	3.9E-05	3.4
160	2.496	0.304	3.8E-05	3.3
180	2.505	0.295	3.7E-05	3.2
200	2.513	0.287	3.6E-05	3.1
220	2.521	0.279	3.6E-05	3.1
240	2.528	0.272	3.5E-05	3.0
		AVERAGE	4.0E-05	3.5



https://galtgeo.sharepoint.com/sites/WAE221033/Shared Documents/02 Qube Infilt Testing/08 Analysis/20231006 - Permeability Inverse Auger Spreadsheets MDS-KS/WAE221033-02 IT Results Combined

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

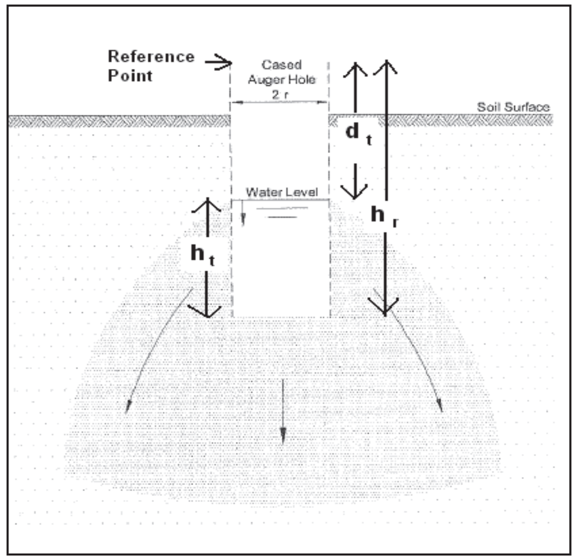
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT04
Test Depth:	2.80 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

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Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

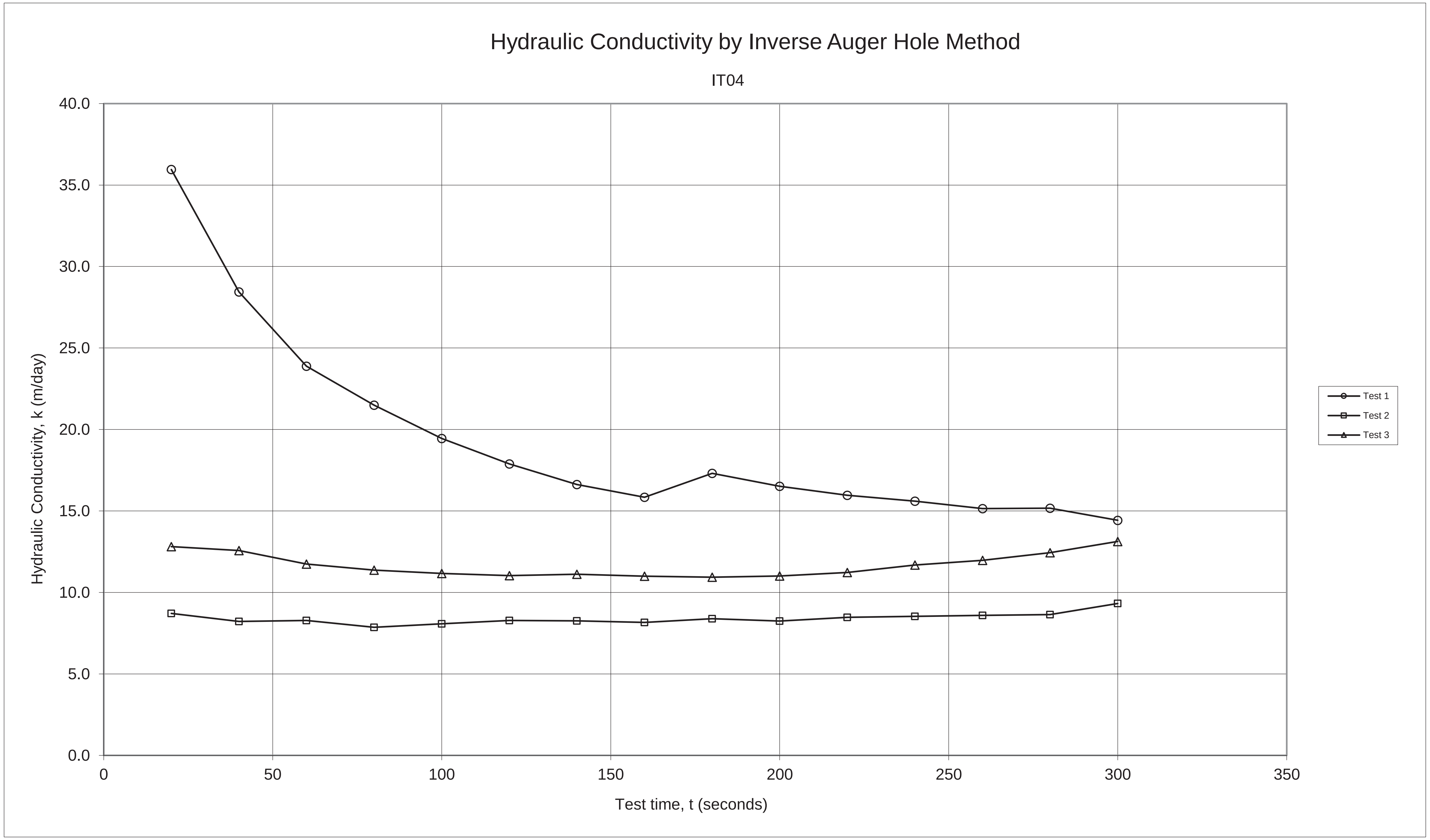
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.74	1.06		
20	2.075	0.725	4.2E-04	36.0
40	2.22	0.58	3.3E-04	28.4
60	2.305	0.495	2.8E-04	23.9
80	2.376	0.424	2.5E-04	21.5
100	2.425	0.375	2.3E-04	19.5
120	2.464	0.336	2.1E-04	17.9
140	2.496	0.304	1.9E-04	16.6
160	2.529	0.271	1.8E-04	15.8
180	2.605	0.195	2.0E-04	17.3
200	2.625	0.175	1.9E-04	16.5
220	2.645	0.155	1.8E-04	16.0
240	2.665	0.135	1.8E-04	15.6
260	2.68	0.12	1.8E-04	15.1
280	2.701	0.099	1.8E-04	15.2
300	2.706	0.094	1.7E-04	14.4
		AVERAGE	2.2E-04	19.3

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.508	0.292		
20	2.535	0.265	1.0E-04	8.7
40	2.557	0.243	9.5E-05	8.2
60	2.579	0.221	9.6E-05	8.3
80	2.595	0.205	9.1E-05	7.9
100	2.615	0.185	9.3E-05	8.1
120	2.634	0.166	9.6E-05	8.3
140	2.649	0.151	9.5E-05	8.3
160	2.662	0.138	9.4E-05	8.2
180	2.678	0.122	9.7E-05	8.4
200	2.688	0.112	9.5E-05	8.2
220	2.702	0.098	9.8E-05	8.5
240	2.713	0.087	9.9E-05	8.5
260	2.723	0.077	9.9E-05	8.6
280	2.732	0.068	1.0E-04	8.6
300	2.748	0.052	1.1E-04	9.3
		AVERAGE	9.7E-05	8.4

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.507	0.293		
20	2.546	0.254	1.5E-04	12.8
40	2.579	0.221	1.5E-04	12.6
60	2.603	0.197	1.4E-04	11.7
80	2.625	0.175	1.3E-04	11.4
100	2.645	0.155	1.3E-04	11.2
120	2.663	0.137	1.3E-04	11.0
140	2.681	0.119	1.3E-04	11.1
160	2.695	0.105	1.3E-04	11.0
180	2.708	0.092	1.3E-04	10.9
200	2.721	0.079	1.3E-04	11.0
220	2.734	0.066	1.3E-04	11.2
240	2.748	0.052	1.4E-04	11.7
260	2.759	0.041	1.4E-04	12.0
280	2.77	0.03	1.4E-04	12.4
300	2.781	0.019	1.5E-04	13.1
		AVERAGE	1.4E-04	11.7



https://galtgeo.sharepoint.com/sites/WAE221033/Shared Documents/02 Qube Infilt Testing/08 Analysis/20231006 - Permeability Inverse Auger Spreadsheets MDS-KS/WAE221033-02 IT Results Combined

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

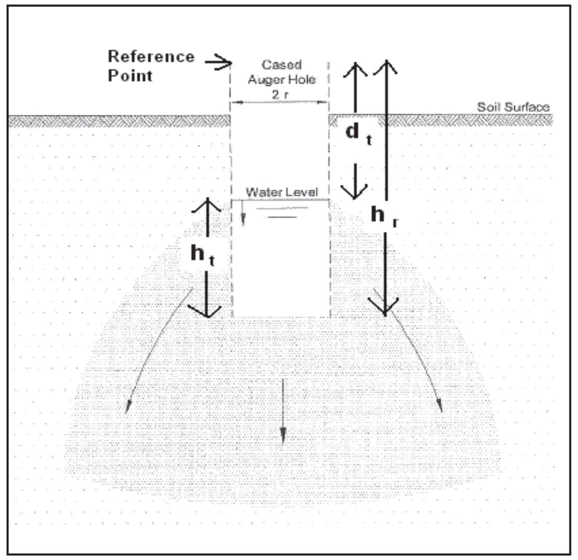
Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09	

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT05
Test Depth:	2.90 m

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

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(orange)	Comment field
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(yellow)	Fixed field

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.9	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

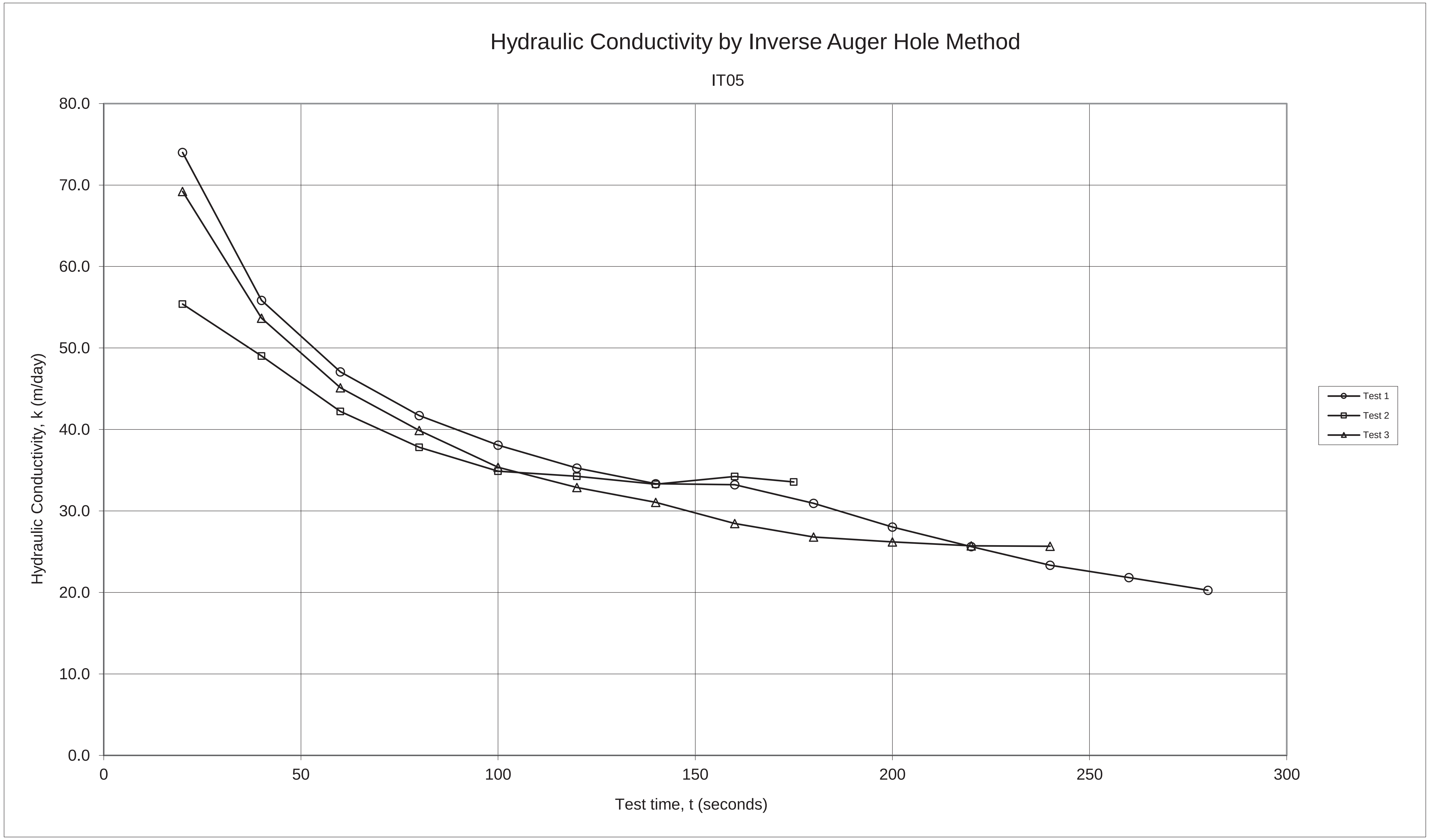
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.91	0.99		
20	2.45	0.45	8.6E-04	74.0
40	2.602	0.298	6.5E-04	55.8
60	2.686	0.214	5.4E-04	47.1
80	2.741	0.159	4.8E-04	41.7
100	2.78	0.12	4.4E-04	38.1
120	2.808	0.092	4.1E-04	35.3
140	2.831	0.069	3.9E-04	33.3
160	2.857	0.043	3.8E-04	33.2
180	2.865	0.035	3.6E-04	30.9
200	2.866	0.034	3.2E-04	28.0
220	2.867	0.033	3.0E-04	25.6
240	2.866	0.034	2.7E-04	23.3
260	2.868	0.032	2.5E-04	21.8
280	2.868	0.032	2.3E-04	20.3
		AVERAGE	4.2E-04	36.3

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.738	1.162		
20	2.253	0.647	6.4E-04	55.4
40	2.491	0.409	5.7E-04	49.0
60	2.601	0.299	4.9E-04	42.2
80	2.673	0.227	4.4E-04	37.8
100	2.726	0.174	4.0E-04	34.9
120	2.78	0.12	4.0E-04	34.3
140	2.815	0.085	3.9E-04	33.3
160	2.852	0.048	4.0E-04	34.2
175	2.865	0.035	3.9E-04	33.6
		AVERAGE	4.6E-04	39.4

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.622	1.278		
20	2.285	0.615	8.0E-04	69.2
40	2.492	0.408	6.2E-04	53.7
60	2.6	0.3	5.2E-04	45.1
80	2.671	0.229	4.6E-04	39.9
100	2.712	0.188	4.1E-04	35.4
120	2.752	0.148	3.8E-04	32.9
140	2.784	0.116	3.6E-04	31.1
160	2.798	0.102	3.3E-04	28.5
180	2.814	0.086	3.1E-04	26.8
200	2.835	0.065	3.0E-04	26.2
220	2.852	0.048	3.0E-04	25.7
240	2.868	0.032	3.0E-04	25.7
		AVERAGE	4.2E-04	36.7



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Hydraulic Conductivity Calculation - Inverse Auger Hole Method

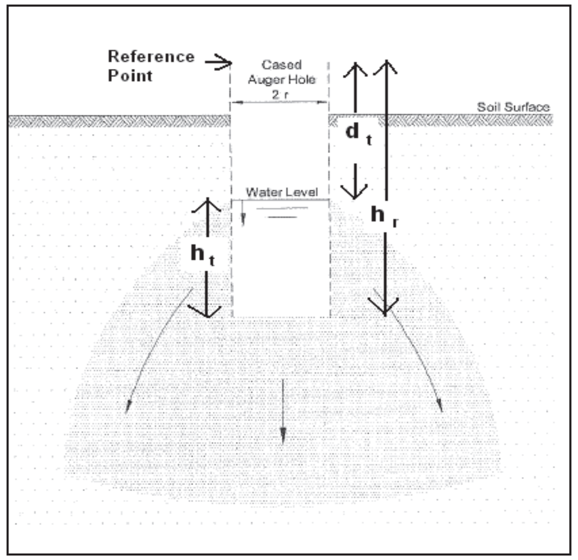
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT06
Test Depth:	2.75 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

(light blue)	Required input
(green)	Calculated field
(orange)	Comment field
(crossed)	Field not used
(yellow)	Fixed field

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.75	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

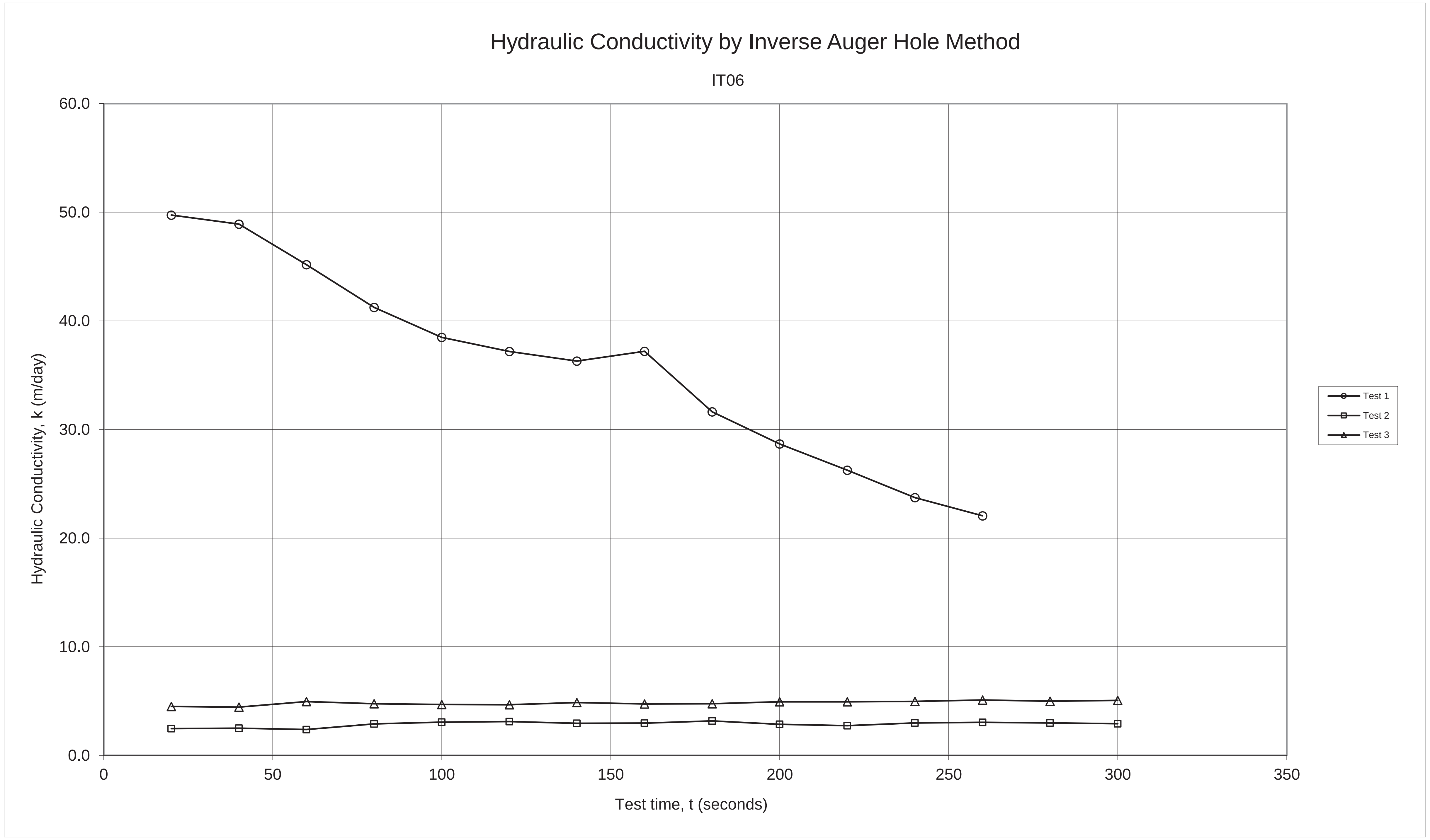
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.862	0.888		
20	2.227	0.523	5.8E-04	49.7
40	2.44	0.31	5.7E-04	48.9
60	2.547	0.203	5.2E-04	45.2
80	2.606	0.144	4.8E-04	41.2
100	2.647	0.103	4.5E-04	38.5
120	2.681	0.069	4.3E-04	37.2
140	2.706	0.044	4.2E-04	36.3
160	2.73	0.02	4.3E-04	37.2
180	2.724	0.026	3.7E-04	31.6
200	2.725	0.025	3.3E-04	28.7
220	2.726	0.024	3.0E-04	26.3
240	2.724	0.026	2.7E-04	23.7
260	2.725	0.025	2.6E-04	22.1
		AVERAGE	4.2E-04	35.9

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.533	0.217		
20	2.539	0.211	2.9E-05	2.5
40	2.545	0.205	2.9E-05	2.5
60	2.55	0.2	2.8E-05	2.4
80	2.56	0.19	3.4E-05	2.9
100	2.568	0.182	3.6E-05	3.1
120	2.575	0.175	3.6E-05	3.1
140	2.579	0.171	3.4E-05	3.0
160	2.585	0.165	3.4E-05	3.0
180	2.594	0.156	3.7E-05	3.2
200	2.594	0.156	3.3E-05	2.9
220	2.597	0.153	3.2E-05	2.7
240	2.607	0.143	3.5E-05	3.0
260	2.613	0.137	3.5E-05	3.0
280	2.617	0.133	3.5E-05	3.0
300	2.62	0.13	3.4E-05	2.9
		AVERAGE	3.3E-05	2.9

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.441	0.309		
20	2.456	0.294	5.2E-05	4.5
40	2.47	0.28	5.1E-05	4.4
60	2.488	0.262	5.7E-05	4.9
80	2.5	0.25	5.5E-05	4.8
100	2.512	0.238	5.4E-05	4.7
120	2.524	0.226	5.4E-05	4.7
140	2.539	0.211	5.6E-05	4.9
160	2.548	0.202	5.5E-05	4.7
180	2.559	0.191	5.5E-05	4.7
200	2.573	0.177	5.7E-05	4.9
220	2.583	0.167	5.7E-05	4.9
240	2.593	0.157	5.7E-05	5.0
260	2.605	0.145	5.9E-05	5.1
280	2.611	0.139	5.8E-05	5.0
300	2.621	0.129	5.9E-05	5.1
		AVERAGE	5.6E-05	4.8



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Hydraulic Conductivity Calculation - Inverse Auger Hole Method

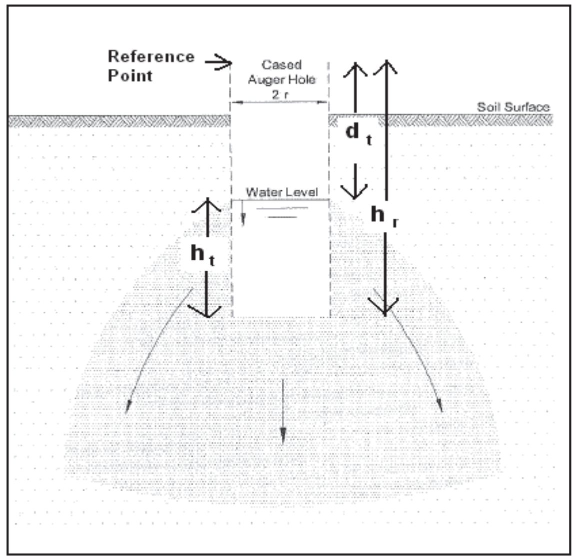
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT07
Test Depth:	2.90 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r\frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

Required input	(blue)
Calculated field	(green)
Comment field	(orange)
Field not used	(crossed)
Fixed field	(yellow)

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

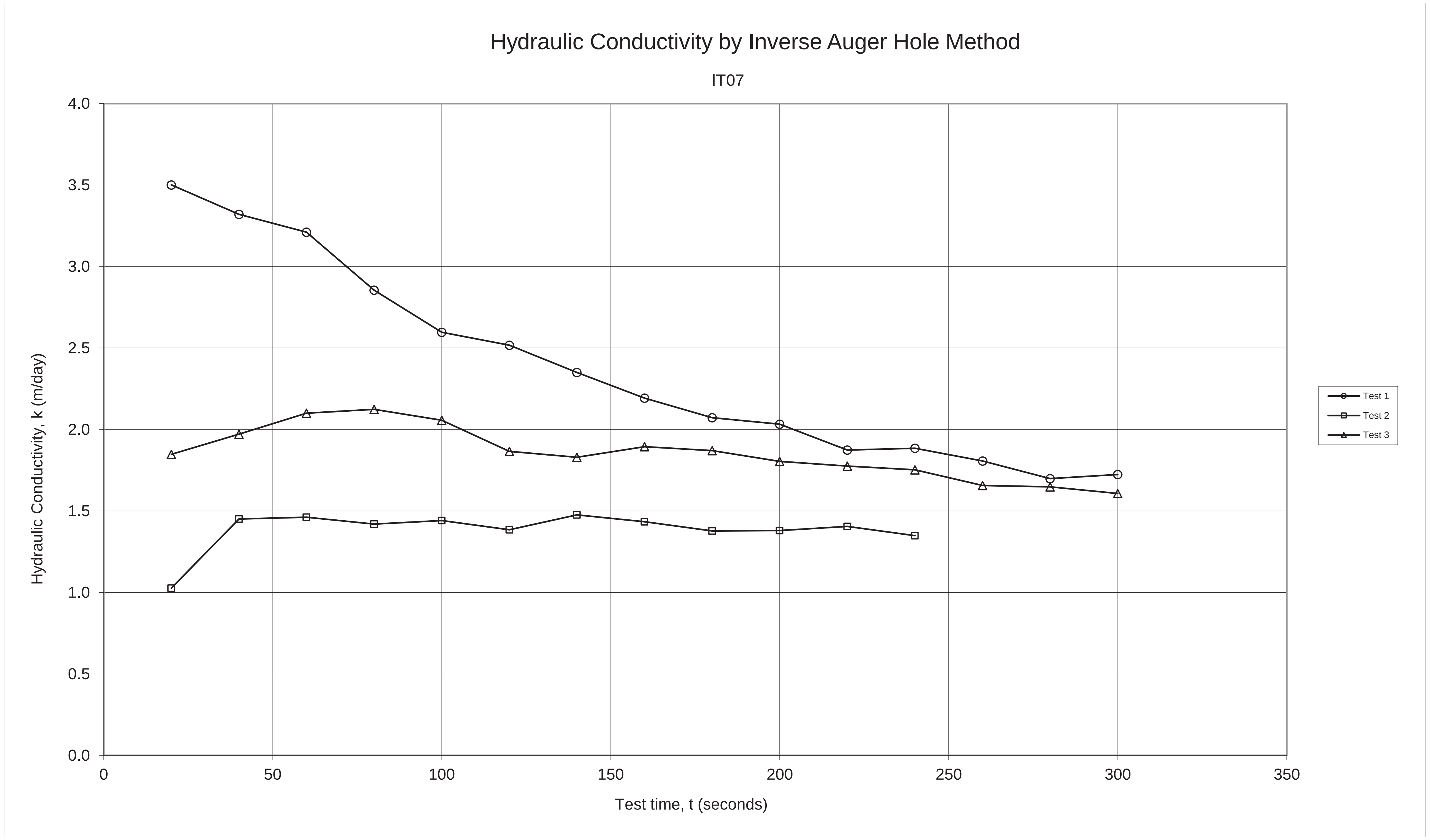
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.399	0.401		
20	2.414	0.386	4.1E-05	3.5
40	2.427	0.373	3.8E-05	3.3
60	2.439	0.361	3.7E-05	3.2
80	2.446	0.354	3.3E-05	2.9
100	2.452	0.348	3.0E-05	2.6
120	2.46	0.34	2.9E-05	2.5
140	2.465	0.335	2.7E-05	2.3
160	2.469	0.331	2.5E-05	2.2
180	2.473	0.327	2.4E-05	2.1
200	2.479	0.321	2.4E-05	2.0
220	2.48	0.32	2.2E-05	1.9
240	2.487	0.313	2.2E-05	1.9
260	2.49	0.31	2.1E-05	1.8
280	2.491	0.309	2.0E-05	1.7
300	2.498	0.302	2.0E-05	1.7
		AVERAGE	2.7E-05	2.4

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.347	0.453		
20	2.352	0.448	1.2E-05	1.0
40	2.361	0.439	1.7E-05	1.5
60	2.368	0.432	1.7E-05	1.5
80	2.374	0.426	1.6E-05	1.4
100	2.381	0.419	1.7E-05	1.4
120	2.386	0.414	1.6E-05	1.4
140	2.395	0.405	1.7E-05	1.5
160	2.4	0.4	1.7E-05	1.4
180	2.404	0.396	1.6E-05	1.4
200	2.41	0.39	1.6E-05	1.4
220	2.417	0.383	1.6E-05	1.4
240	2.42	0.38	1.6E-05	1.3
		AVERAGE	1.6E-05	1.4

Test 3

t (s)		h_t (m)	K (m/s)	K (m/day)
0	2.345	0.455		
20	2.354	0.446	2.1E-05	1.8
40	2.364	0.436	2.3E-05	2.0
60	2.375	0.425	2.4E-05	2.1
80	2.385	0.415	2.5E-05	2.1
100	2.393	0.407	2.4E-05	2.1
120	2.397	0.403	2.2E-05	1.9
140	2.404	0.396	2.1E-05	1.8
160	2.414	0.386	2.2E-05	1.9
180	2.421	0.379	2.2E-05	1.9
200	2.426	0.374	2.1E-05	1.8
220	2.432	0.368	2.1E-05	1.8
240	2.438	0.362	2.0E-05	1.8
260	2.44	0.36	1.9E-05	1.7
280	2.446	0.354	1.9E-05	1.6
300	2.45	0.35	1.9E-05	1.6
		AVERAGE	2.1E-05	1.9



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Hydraulic Conductivity Calculation - Inverse Auger Hole Method

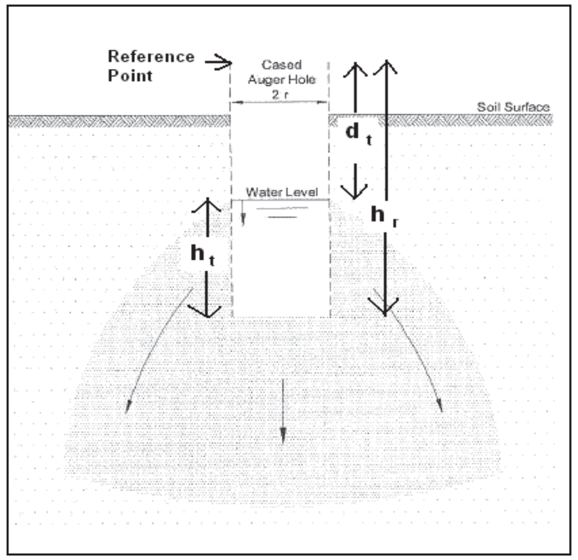
Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09	

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT08
Test Depth:	2.75 m

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

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Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.75	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

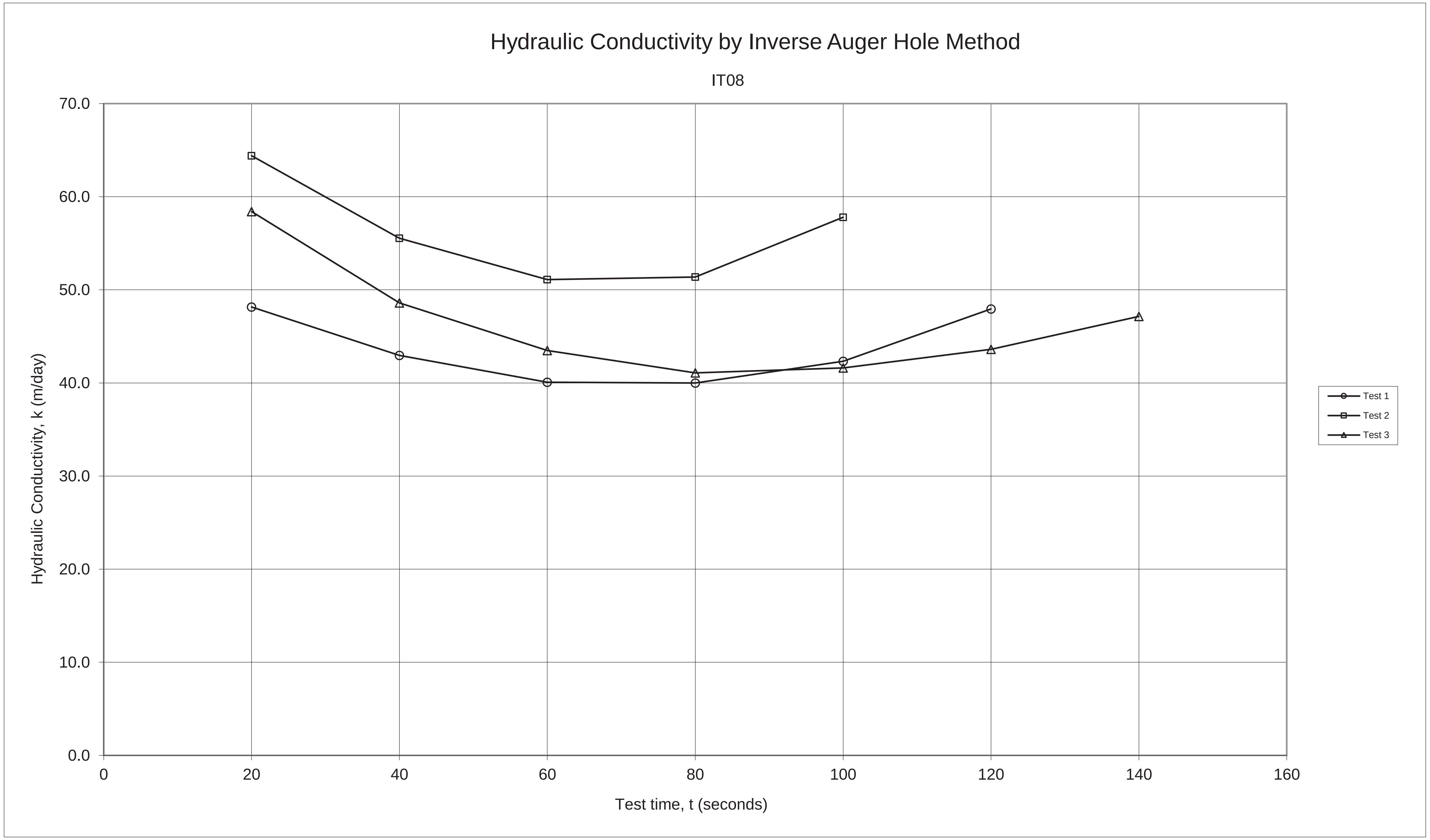
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.105	0.645		
20	2.366	0.384	5.6E-04	48.2
40	2.497	0.253	5.0E-04	43.0
60	2.579	0.171	4.6E-04	40.1
80	2.644	0.106	4.6E-04	40.0
100	2.697	0.053	4.9E-04	42.3
120	2.738	0.012	5.5E-04	47.9
		AVERAGE	5.0E-04	43.6

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.096	0.654		
20	2.424	0.326	7.5E-04	64.4
40	2.557	0.193	6.4E-04	55.5
60	2.633	0.117	5.9E-04	51.1
80	2.691	0.059	5.9E-04	51.4
100	2.738	0.012	6.7E-04	57.8
		AVERAGE	6.5E-04	56.0

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.069	0.681		
20	2.387	0.363	6.8E-04	58.4
40	2.514	0.236	5.6E-04	48.6
60	2.589	0.161	5.0E-04	43.5
80	2.643	0.107	4.8E-04	41.1
100	2.69	0.06	4.8E-04	41.6
120	2.725	0.025	5.0E-04	43.6
140	2.749	0.001	5.5E-04	47.1
		AVERAGE	5.4E-04	46.3



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Hydraulic Conductivity Calculation - Inverse Auger Hole Method

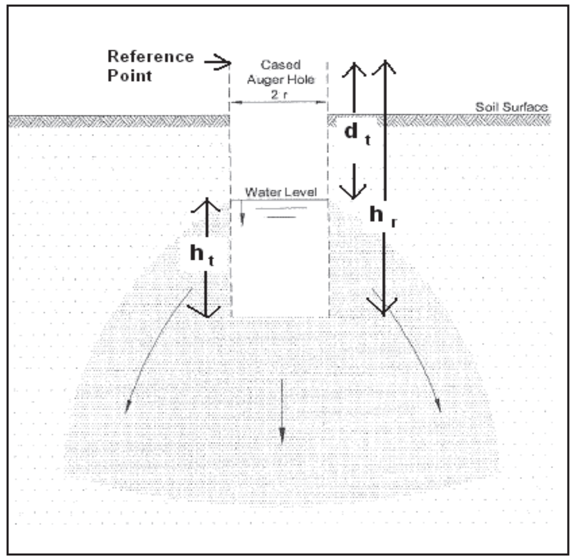
Galt Geotechnics

Spreadsheet author:	ORW
	17-Oct-09

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT09
Test Depth:	2.80 m

$$K = 1.15r\,\frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

Required input	
Calculated field	
Comment field	
Field not used	
Fixed field	

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

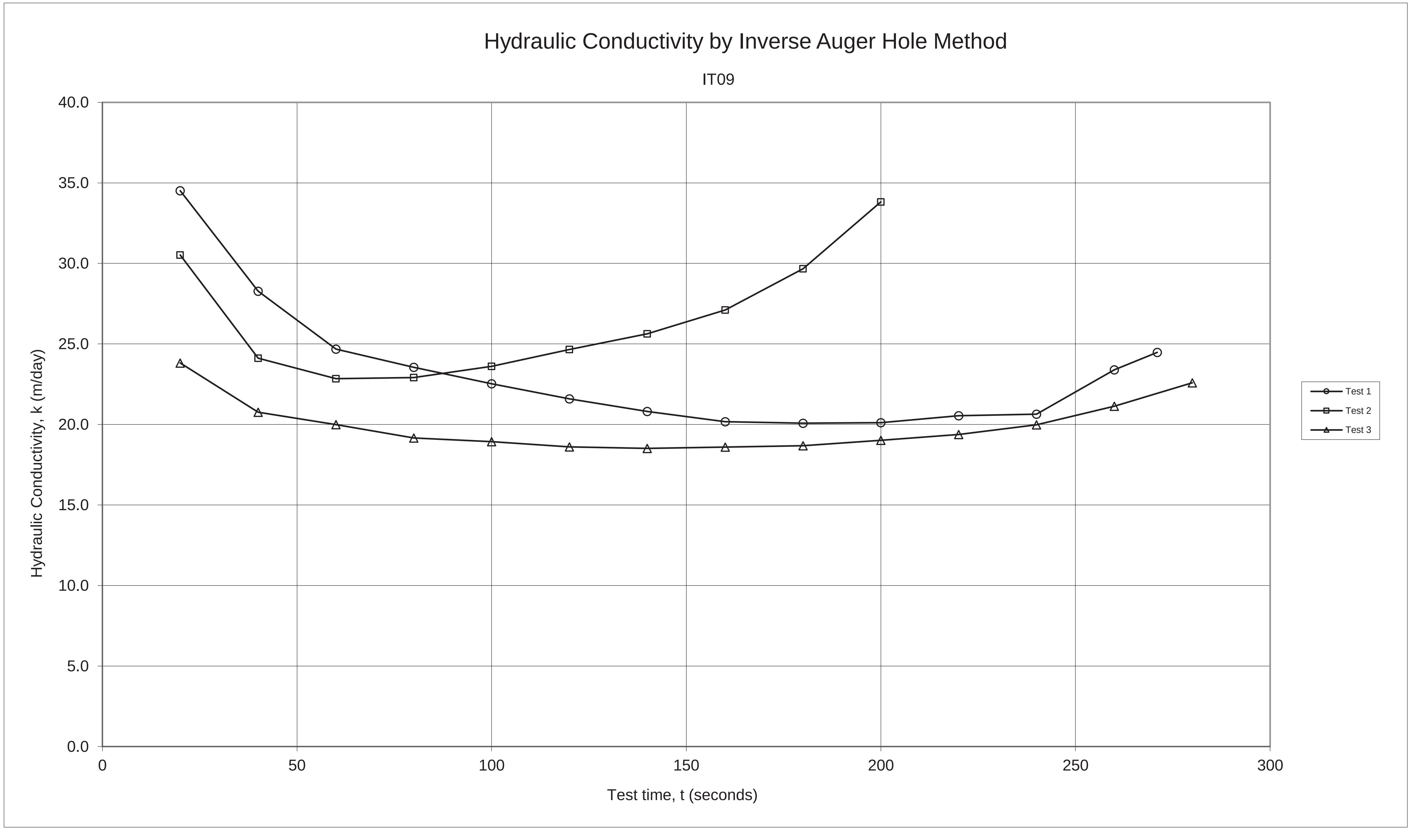
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.803	0.997		
20	2.108	0.692	4.0E-04	34.5
40	2.253	0.547	3.3E-04	28.3
60	2.347	0.453	2.9E-04	24.7
80	2.436	0.364	2.7E-04	23.5
100	2.503	0.297	2.6E-04	22.5
120	2.554	0.246	2.5E-04	21.6
140	2.595	0.205	2.4E-04	20.8
160	2.629	0.171	2.3E-04	20.2
180	2.664	0.136	2.3E-04	20.1
200	2.694	0.106	2.3E-04	20.1
220	2.723	0.077	2.4E-04	20.5
240	2.743	0.057	2.4E-04	20.6
260	2.778	0.022	2.7E-04	23.4
271	2.789	0.011	2.8E-04	24.5
		AVERAGE	2.7E-04	23.2

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.829	0.971		
20	2.097	0.703	3.5E-04	30.5
40	2.218	0.582	2.8E-04	24.1
60	2.332	0.468	2.6E-04	22.8
80	2.436	0.364	2.7E-04	22.9
100	2.528	0.272	2.7E-04	23.6
120	2.606	0.194	2.9E-04	24.7
140	2.666	0.134	3.0E-04	25.6
160	2.716	0.084	3.1E-04	27.1
180	2.759	0.041	3.4E-04	29.7
200	2.792	0.008	3.9E-04	33.8
		AVERAGE	3.1E-04	26.5

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.848	0.952		
20	2.06	0.74	2.8E-04	23.8
40	2.187	0.613	2.4E-04	20.8
60	2.297	0.503	2.3E-04	20.0
80	2.38	0.42	2.2E-04	19.2
100	2.455	0.345	2.2E-04	18.9
120	2.514	0.286	2.2E-04	18.6
140	2.566	0.234	2.1E-04	18.5
160	2.612	0.188	2.2E-04	18.6
180	2.65	0.15	2.2E-04	18.7
200	2.685	0.115	2.2E-04	19.0
220	2.714	0.086	2.2E-04	19.4
240	2.74	0.06	2.3E-04	20.0
260	2.765	0.035	2.4E-04	21.1
280	2.785	0.015	2.6E-04	22.6
		AVERAGE	2.3E-04	19.9



https://galtgeo.sharepoint.com/sites/WAE221033/Shared Documents/02 Qube Infilt Testing/08 Analysis/20231006 - Permeability Inverse Auger Spreadsheets MDS-KS/WAE221033-02 IT Results Combined

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

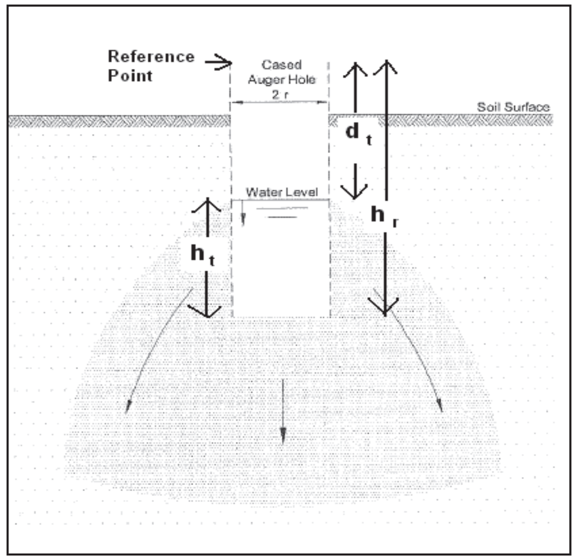
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT10
Test Depth:	2.80 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

	Required input
	Calculated field
	Comment field
	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

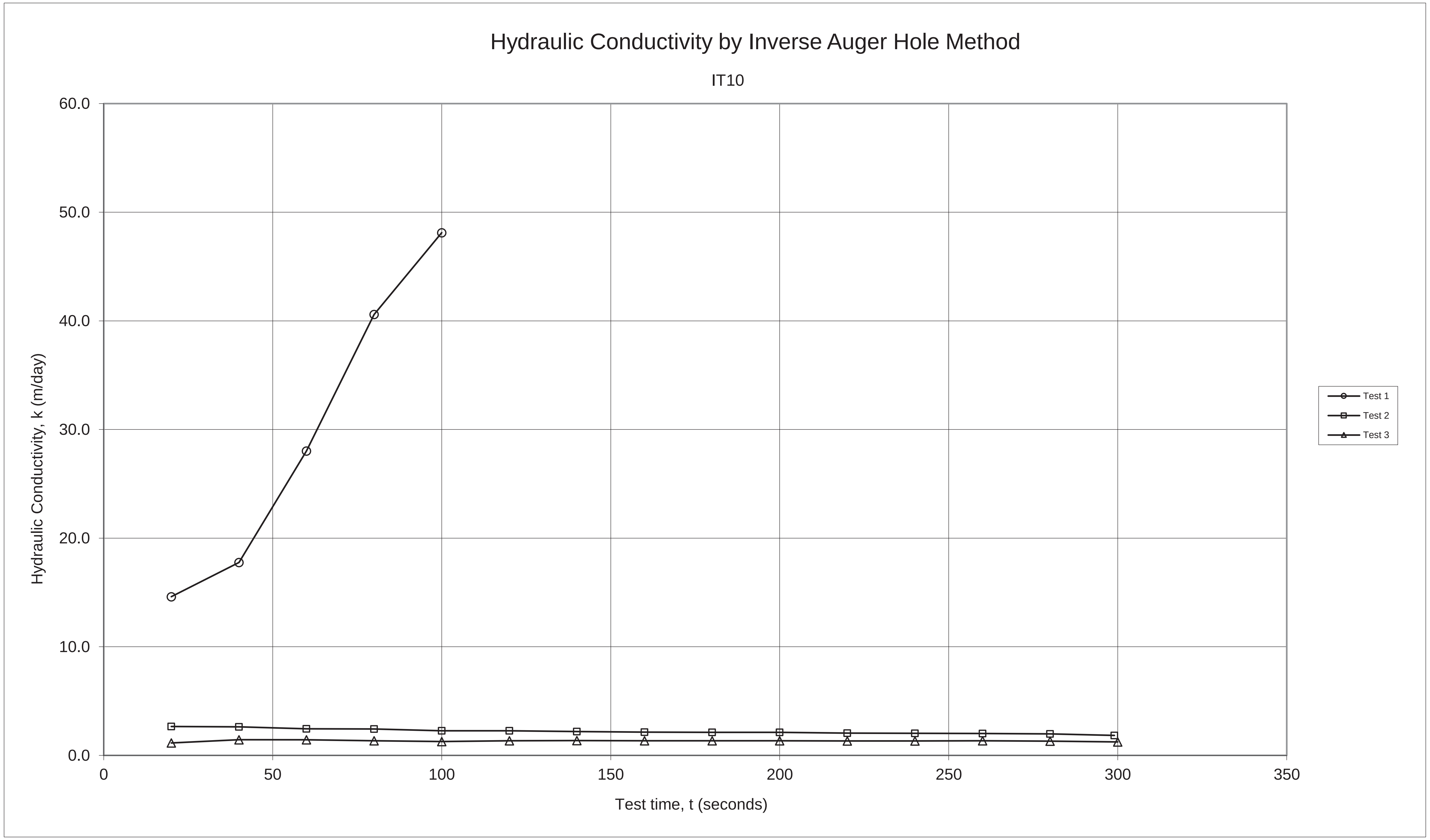
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.899	0.901		
20	2.028	0.772	1.7E-04	14.6
40	2.182	0.618	2.1E-04	17.8
60	2.434	0.366	3.2E-04	28.0
80	2.649	0.151	4.7E-04	40.6
100	2.745	0.055	5.6E-04	48.1
		AVERAGE	3.5E-04	29.8

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.971	0.829		
20	1.994	0.806	3.1E-05	2.7
40	2.016	0.784	3.1E-05	2.6
60	2.033	0.767	2.8E-05	2.4
80	2.052	0.748	2.8E-05	2.4
100	2.065	0.735	2.6E-05	2.3
120	2.082	0.718	2.6E-05	2.3
140	2.096	0.704	2.5E-05	2.2
160	2.109	0.691	2.5E-05	2.1
180	2.123	0.677	2.5E-05	2.1
200	2.138	0.662	2.5E-05	2.1
220	2.147	0.653	2.4E-05	2.0
240	2.16	0.64	2.4E-05	2.0
260	2.173	0.627	2.3E-05	2.0
280	2.182	0.618	2.3E-05	2.0
299	2.181	0.619	2.1E-05	1.8
		AVERAGE	2.6E-05	2.2

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.969	0.831		
20	1.979	0.821	1.3E-05	1.1
40	1.994	0.806	1.7E-05	1.4
60	2.006	0.794	1.7E-05	1.4
80	2.015	0.785	1.6E-05	1.3
100	2.023	0.777	1.5E-05	1.3
120	2.037	0.763	1.6E-05	1.3
140	2.049	0.751	1.6E-05	1.4
160	2.059	0.741	1.6E-05	1.4
180	2.069	0.731	1.6E-05	1.3
200	2.08	0.72	1.6E-05	1.4
220	2.089	0.711	1.5E-05	1.3
240	2.099	0.701	1.5E-05	1.3
260	2.109	0.691	1.5E-05	1.3
280	2.116	0.684	1.5E-05	1.3
300	2.118	0.682	1.4E-05	1.2
		AVERAGE	1.5E-05	1.3


Hydraulic Conductivity by Inverse Auger Hole Method
IT10
Hydraulic Conductivity, k (m/day)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
50
100
150
200
250
300
350
Test time, t (seconds)
Test 1
Test 2
Test 3

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

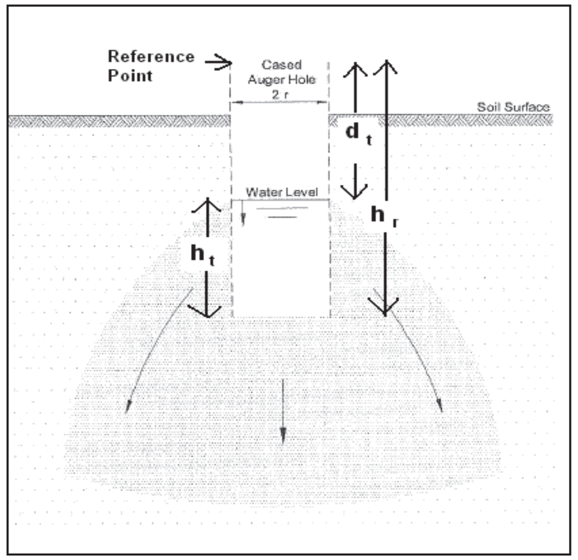
Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT11
Test Depth:	2.75 m

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

Required input	
Calculated field	
Comment field	
Field not used	
Fixed field	

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.75	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

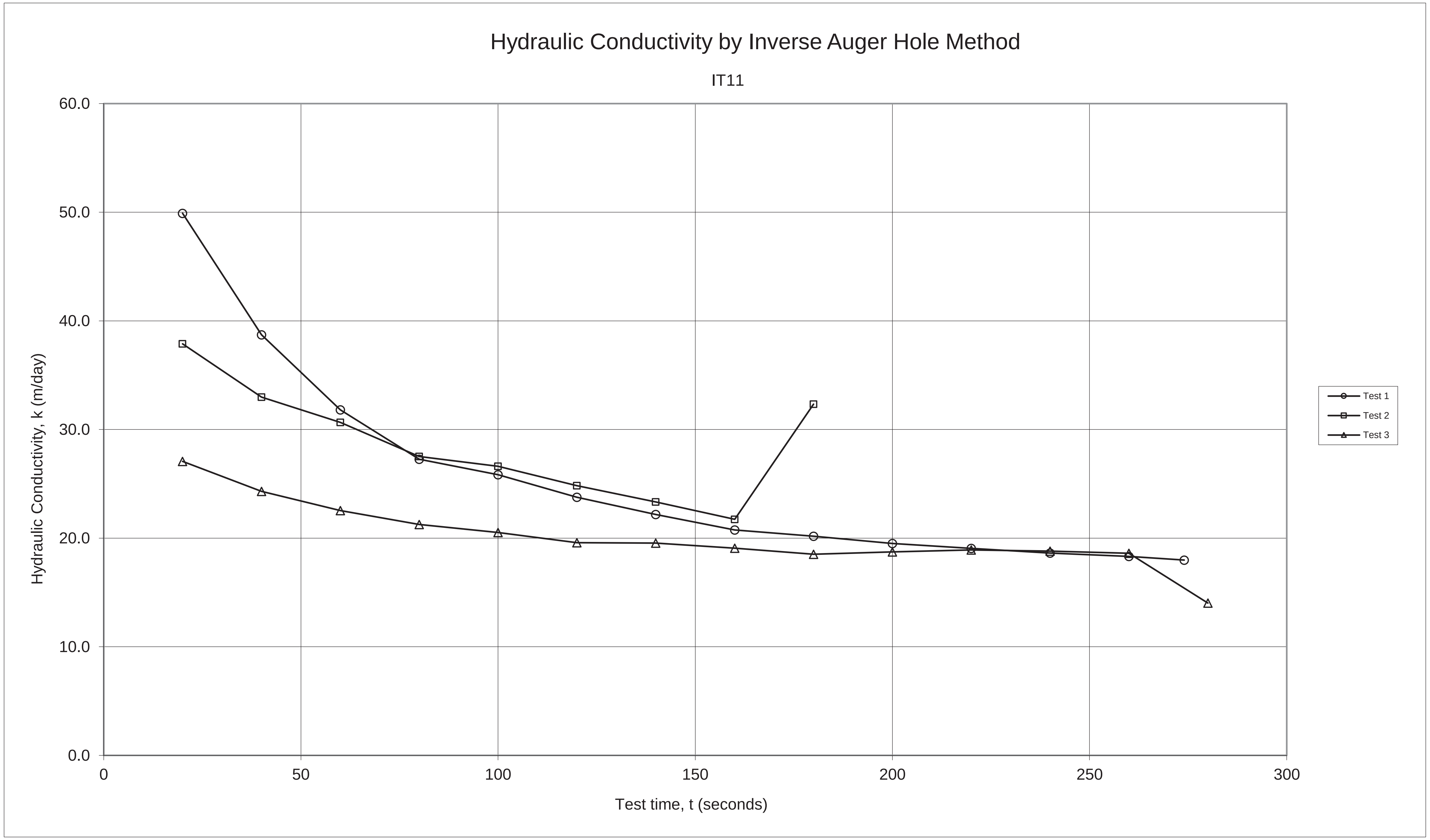
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.919	0.831		
20	2.262	0.488	5.8E-04	49.9
40	2.388	0.362	4.5E-04	38.7
60	2.453	0.297	3.7E-04	31.8
80	2.495	0.255	3.2E-04	27.3
100	2.547	0.203	3.0E-04	25.8
120	2.576	0.174	2.8E-04	23.8
140	2.6	0.15	2.6E-04	22.2
160	2.618	0.132	2.4E-04	20.7
180	2.641	0.109	2.3E-04	20.2
200	2.658	0.092	2.3E-04	19.5
220	2.674	0.076	2.2E-04	19.1
240	2.687	0.063	2.2E-04	18.6
260	2.699	0.051	2.1E-04	18.3
274	2.705	0.045	2.1E-04	18.0
		AVERAGE	2.9E-04	25.3

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.302	0.448		
20	2.454	0.296	4.4E-04	37.9
40	2.534	0.216	3.8E-04	33.0
60	2.59	0.16	3.5E-04	30.6
80	2.621	0.129	3.2E-04	27.5
100	2.653	0.097	3.1E-04	26.6
120	2.671	0.079	2.9E-04	24.8
140	2.685	0.065	2.7E-04	23.3
160	2.694	0.056	2.5E-04	21.7
180	2.749	0.001	3.7E-04	32.3
		AVERAGE	3.3E-04	28.6

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.308	0.442		
20	2.421	0.329	3.1E-04	27.1
40	2.491	0.259	2.8E-04	24.3
60	2.541	0.209	2.6E-04	22.5
80	2.579	0.171	2.5E-04	21.3
100	2.611	0.139	2.4E-04	20.5
120	2.634	0.116	2.3E-04	19.6
140	2.659	0.091	2.3E-04	19.5
160	2.676	0.074	2.2E-04	19.1
180	2.689	0.061	2.1E-04	18.5
200	2.705	0.045	2.2E-04	18.7
220	2.718	0.032	2.2E-04	18.9
240	2.727	0.023	2.2E-04	18.8
260	2.734	0.016	2.2E-04	18.6
280	2.711	0.039	1.6E-04	14.0
		AVERAGE	2.3E-04	20.1


Hydraulic Conductivity by Inverse Auger Hole Method
IT11
Hydraulic Conductivity, k (m/day)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
50
100
150
200
250
300
Test time, t (seconds)
Test 1
Test 2
Test 3

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

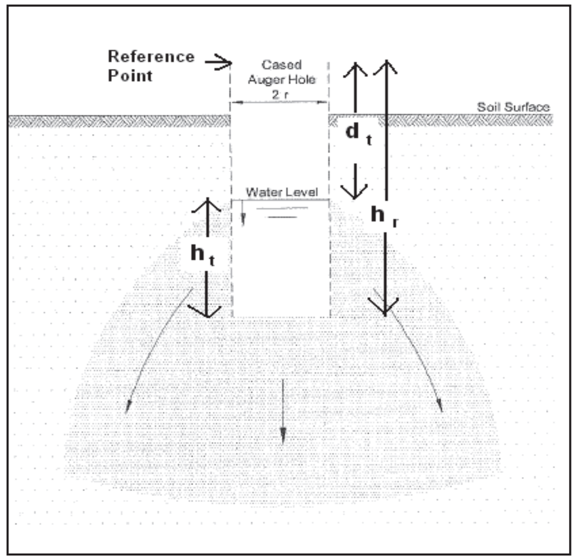
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT12
Test Depth:	2.90 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

Required input	
Calculated field	
Comment field	
Field not used	
Fixed field	

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.9	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

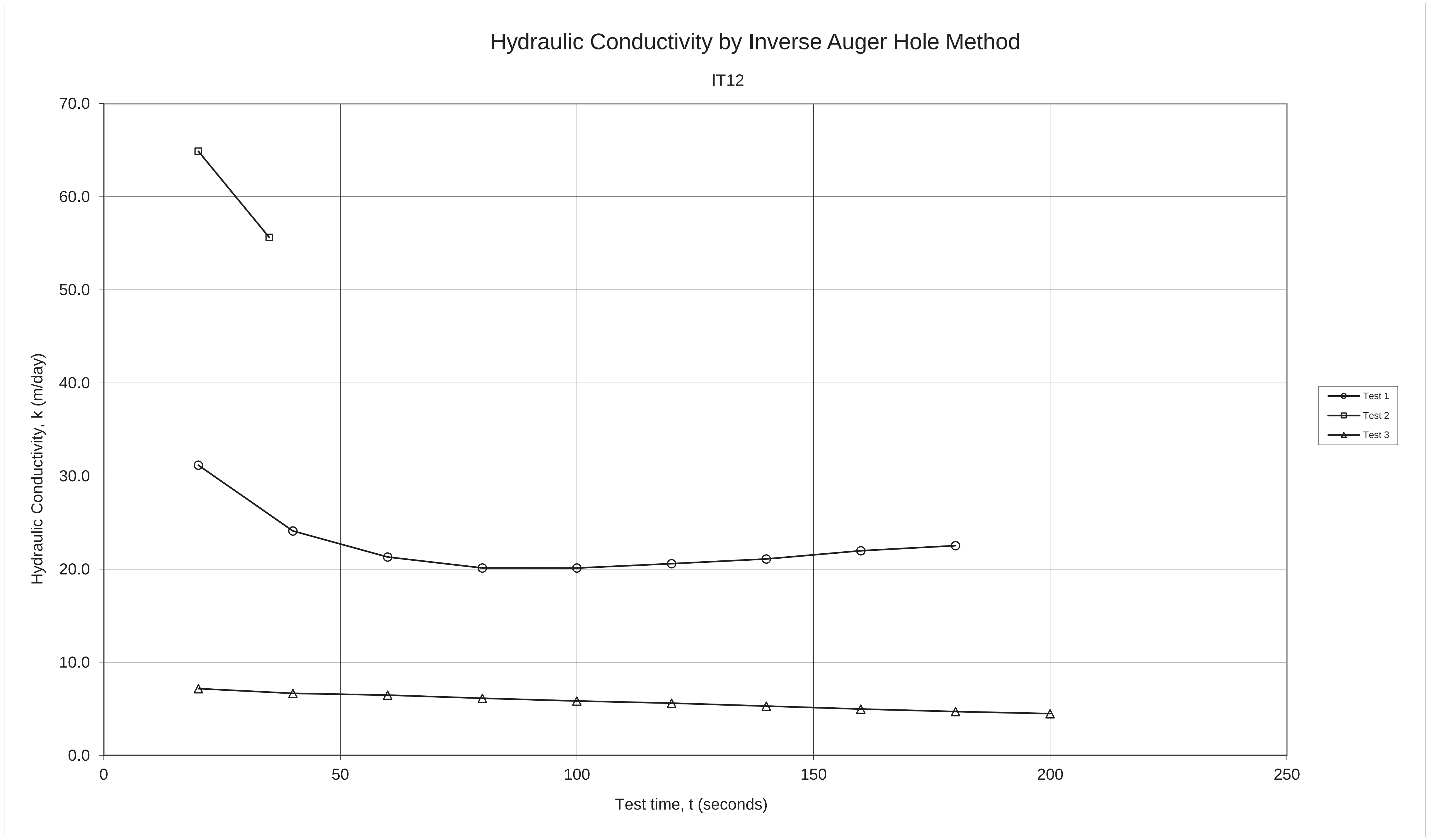
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.757	1.143		
20	2.077	0.823	3.6E-04	31.2
40	2.213	0.687	2.8E-04	24.1
60	2.319	0.581	2.5E-04	21.3
80	2.414	0.486	2.3E-04	20.1
100	2.509	0.391	2.3E-04	20.1
120	2.596	0.304	2.4E-04	20.6
140	2.668	0.232	2.4E-04	21.1
160	2.732	0.168	2.5E-04	22.0
180	2.778	0.122	2.6E-04	22.5
		AVERAGE	2.6E-04	22.6

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.586	0.314		
20	2.75	0.15	7.5E-04	64.9
35	2.799	0.101	6.4E-04	55.6
		AVERAGE	7.0E-04	60.2

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.206	0.694		
20	2.257	0.643	8.3E-05	7.2
40	2.298	0.602	7.7E-05	6.7
60	2.336	0.564	7.5E-05	6.5
80	2.366	0.534	7.1E-05	6.1
100	2.392	0.508	6.8E-05	5.8
120	2.416	0.484	6.5E-05	5.6
140	2.433	0.467	6.1E-05	5.3
160	2.447	0.453	5.8E-05	5.0
180	2.459	0.441	5.4E-05	4.7
200	2.471	0.429	5.2E-05	4.5
		AVERAGE	6.6E-05	5.7



https://galtgeo.sharepoint.com/sites/WAE221033/Shared Documents/02 Qube Infilt Testing/08 Analysis/20231006 - Permeability Inverse Auger Spreadsheets MDS-KS/WAE221033-02 IT Results Combined

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

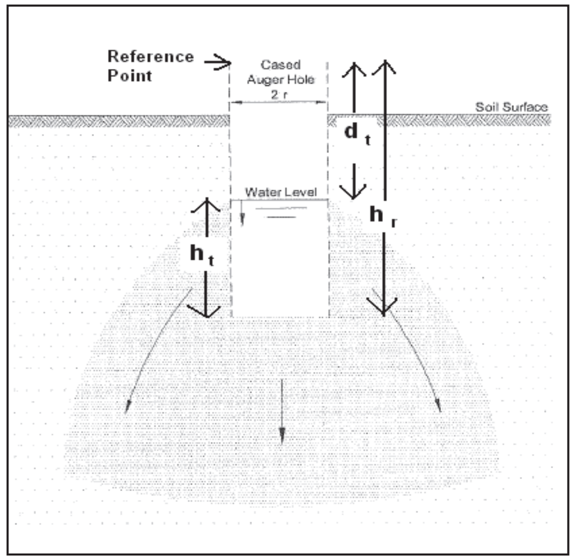
Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT13
Test Depth:	2.80 m

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

(blue)	Required input
(green)	Calculated field
(orange)	Comment field
(crossed)	Field not used
(yellow)	Fixed field

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

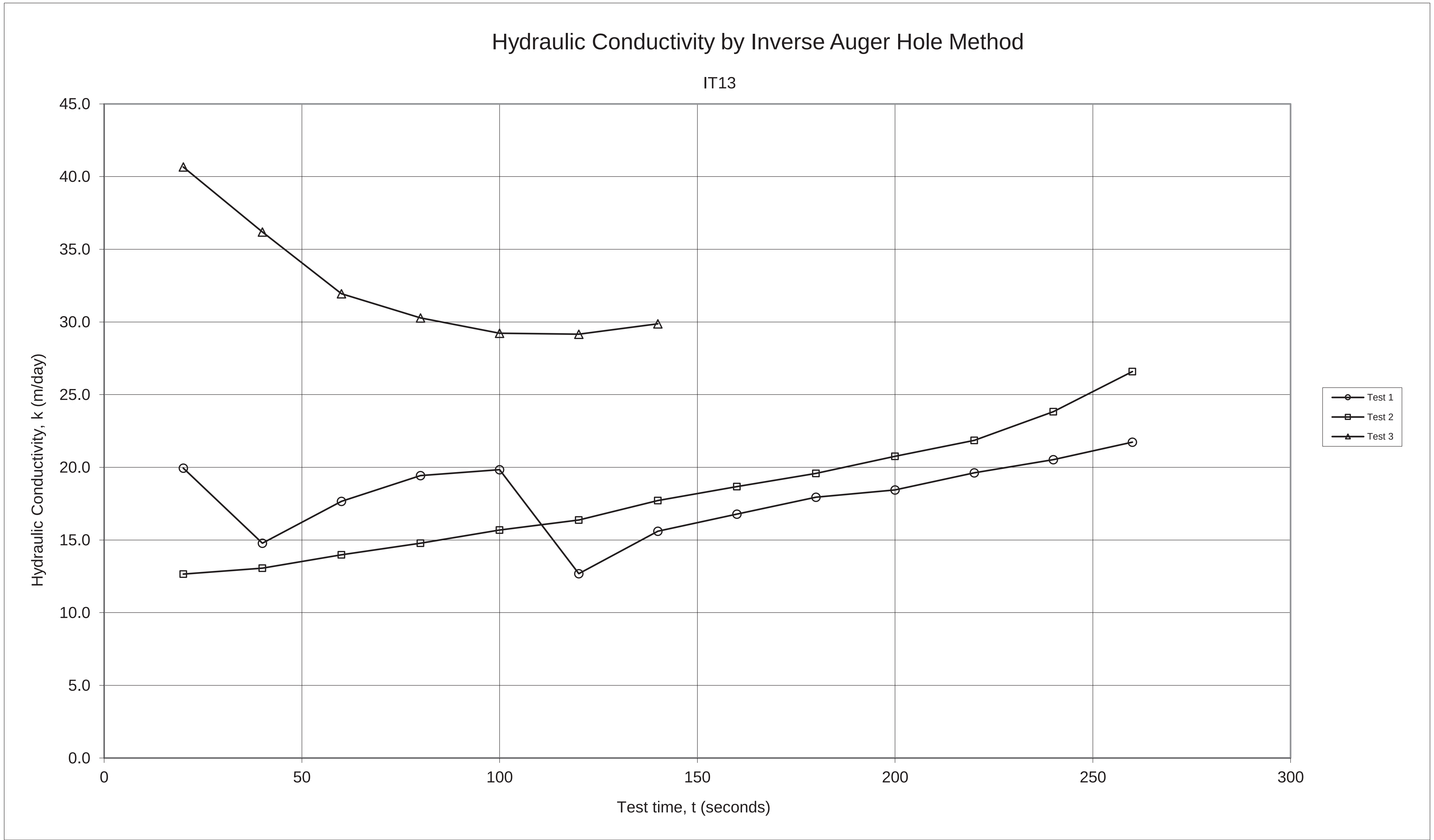
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.171	0.629		
20	2.292	0.508	2.3E-04	19.9
40	2.342	0.458	1.7E-04	14.8
60	2.445	0.355	2.0E-04	17.7
80	2.53	0.27	2.2E-04	19.4
100	2.588	0.212	2.3E-04	19.8
120	2.525	0.275	1.5E-04	12.7
140	2.611	0.189	1.8E-04	15.6
160	2.659	0.141	1.9E-04	16.8
180	2.699	0.101	2.1E-04	17.9
200	2.725	0.075	2.1E-04	18.4
220	2.752	0.048	2.3E-04	19.6
240	2.771	0.029	2.4E-04	20.5
260	2.787	0.013	2.5E-04	21.7
		AVERAGE	2.1E-04	18.1

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.996	0.804		
20	2.097	0.703	1.5E-04	12.7
40	2.191	0.609	1.5E-04	13.1
60	2.286	0.514	1.6E-04	14.0
80	2.373	0.427	1.7E-04	14.8
100	2.454	0.346	1.8E-04	15.7
120	2.522	0.278	1.9E-04	16.4
140	2.592	0.208	2.0E-04	17.7
160	2.645	0.155	2.2E-04	18.7
180	2.688	0.112	2.3E-04	19.6
200	2.725	0.075	2.4E-04	20.8
220	2.753	0.047	2.5E-04	21.9
240	2.779	0.021	2.8E-04	23.8
260	2.799	0.001	3.1E-04	26.6
		AVERAGE	2.1E-04	18.1

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.577	0.223		
20	2.661	0.139	4.7E-04	40.7
40	2.706	0.094	4.2E-04	36.2
60	2.731	0.069	3.7E-04	31.9
80	2.752	0.048	3.5E-04	30.3
100	2.768	0.032	3.4E-04	29.2
120	2.782	0.018	3.4E-04	29.2
140	2.794	0.006	3.5E-04	29.9
		AVERAGE	3.8E-04	32.5



https://galtgeo.sharepoint.com/sites/WAE221033/Shared Documents/02 Qube Infilt Testing/08 Analysis/20231006 - Permeability Inverse Auger Spreadsheets MDS-KS/WAE221033-02 IT Results Combined

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114

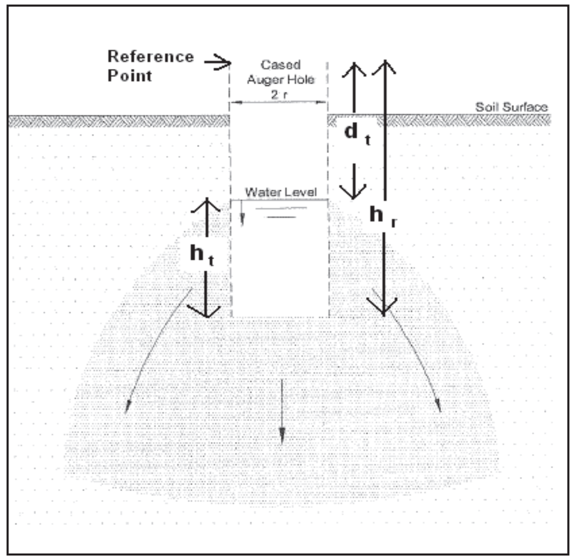
Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT14
Test Depth:	2.80 m

$$K = 1.15r\frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

Spreadsheet Legend

	Required input
	Calculated field
	Comment field
	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m



Test 1

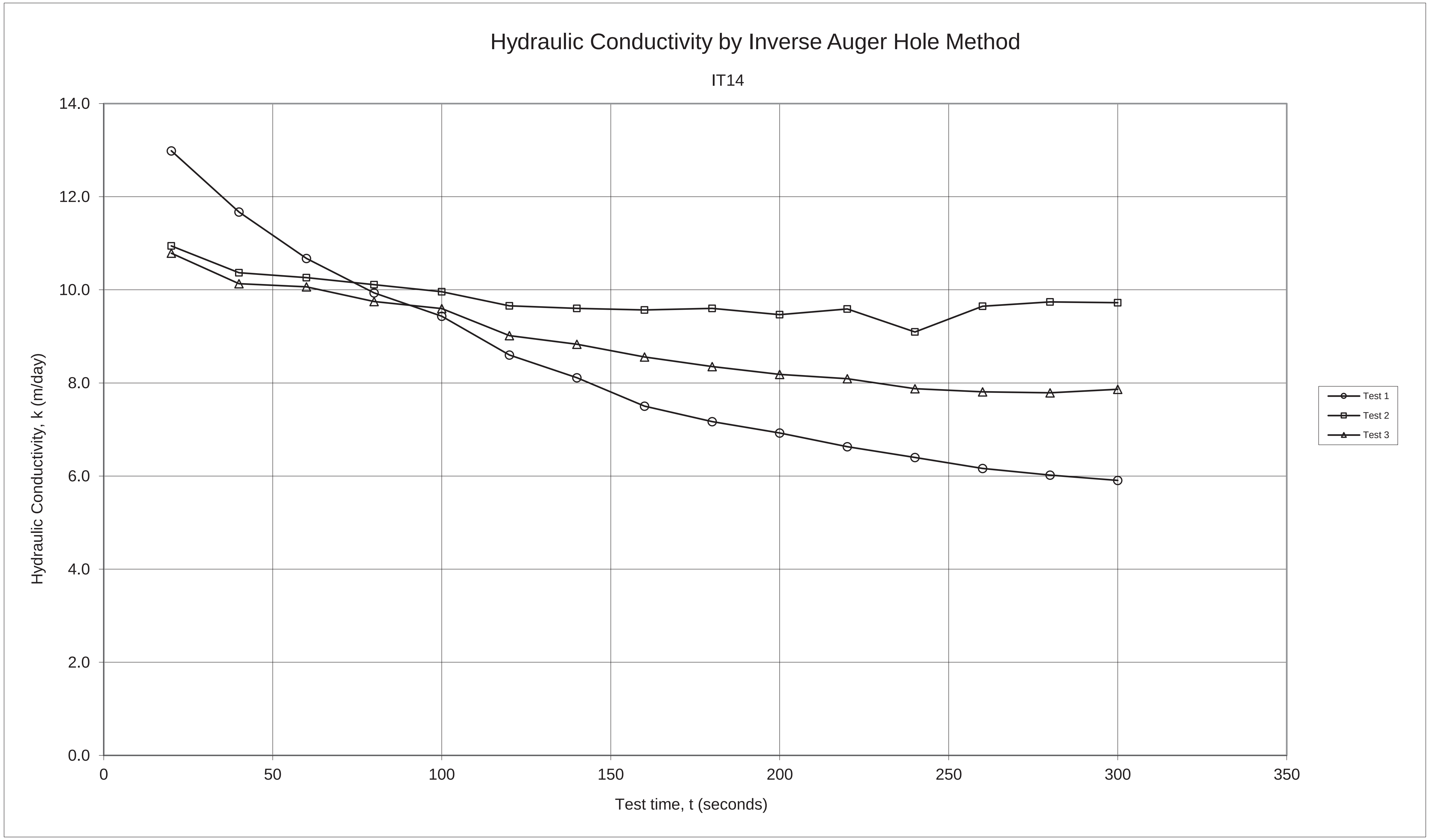
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.495	0.305		
20	2.536	0.264	1.5E-04	13.0
40	2.565	0.235	1.4E-04	11.7
60	2.587	0.213	1.2E-04	10.7
80	2.605	0.195	1.1E-04	9.9
100	2.621	0.179	1.1E-04	9.4
120	2.63	0.17	1.0E-04	8.6
140	2.64	0.16	9.4E-05	8.1
160	2.646	0.154	8.7E-05	7.5
180	2.654	0.146	8.3E-05	7.2
200	2.662	0.138	8.0E-05	6.9
220	2.668	0.132	7.7E-05	6.6
240	2.674	0.126	7.4E-05	6.4
260	2.679	0.121	7.1E-05	6.2
280	2.685	0.115	7.0E-05	6.0
300	2.691	0.109	6.8E-05	5.9
		AVERAGE	9.6E-05	8.3

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.344	0.456		
20	2.395	0.405	1.3E-04	10.9
40	2.436	0.364	1.2E-04	10.4
60	2.474	0.326	1.2E-04	10.3
80	2.507	0.293	1.2E-04	10.1
100	2.536	0.264	1.2E-04	10.0
120	2.559	0.241	1.1E-04	9.7
140	2.583	0.217	1.1E-04	9.6
160	2.605	0.195	1.1E-04	9.6
180	2.626	0.174	1.1E-04	9.6
200	2.642	0.158	1.1E-04	9.5
220	2.661	0.139	1.1E-04	9.6
240	2.667	0.133	1.1E-04	9.1
260	2.691	0.109	1.1E-04	9.6
280	2.705	0.095	1.1E-04	9.7
300	2.716	0.084	1.1E-04	9.7
		AVERAGE	1.1E-04	9.8

Test 3

t (s)		h_t (m)	K (m/s)	K (m/day)
0	2.366	0.434		
20	2.414	0.386	1.2E-04	10.8
40	2.452	0.348	1.2E-04	10.1
60	2.488	0.312	1.2E-04	10.1
80	2.517	0.283	1.1E-04	9.7
100	2.544	0.256	1.1E-04	9.6
120	2.561	0.239	1.0E-04	9.0
140	2.581	0.219	1.0E-04	8.8
160	2.597	0.203	9.9E-05	8.6
180	2.612	0.188	9.7E-05	8.4
200	2.626	0.174	9.5E-05	8.2
220	2.64	0.16	9.4E-05	8.1
240	2.65	0.15	9.1E-05	7.9
260	2.662	0.138	9.0E-05	7.8
280	2.674	0.126	9.0E-05	7.8
300	2.687	0.113	9.1E-05	7.9
		AVERAGE	1.0E-04	8.8



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Hydraulic Conductivity Calculation - Inverse Auger Hole Method

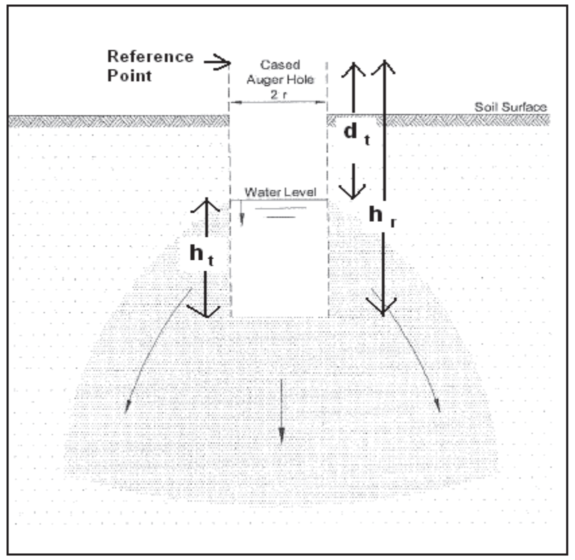
Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT15
Test Depth:	1.00 m

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$



Spreadsheet Legend

	Required input
	Calculated field
	Comment field
	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	1	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

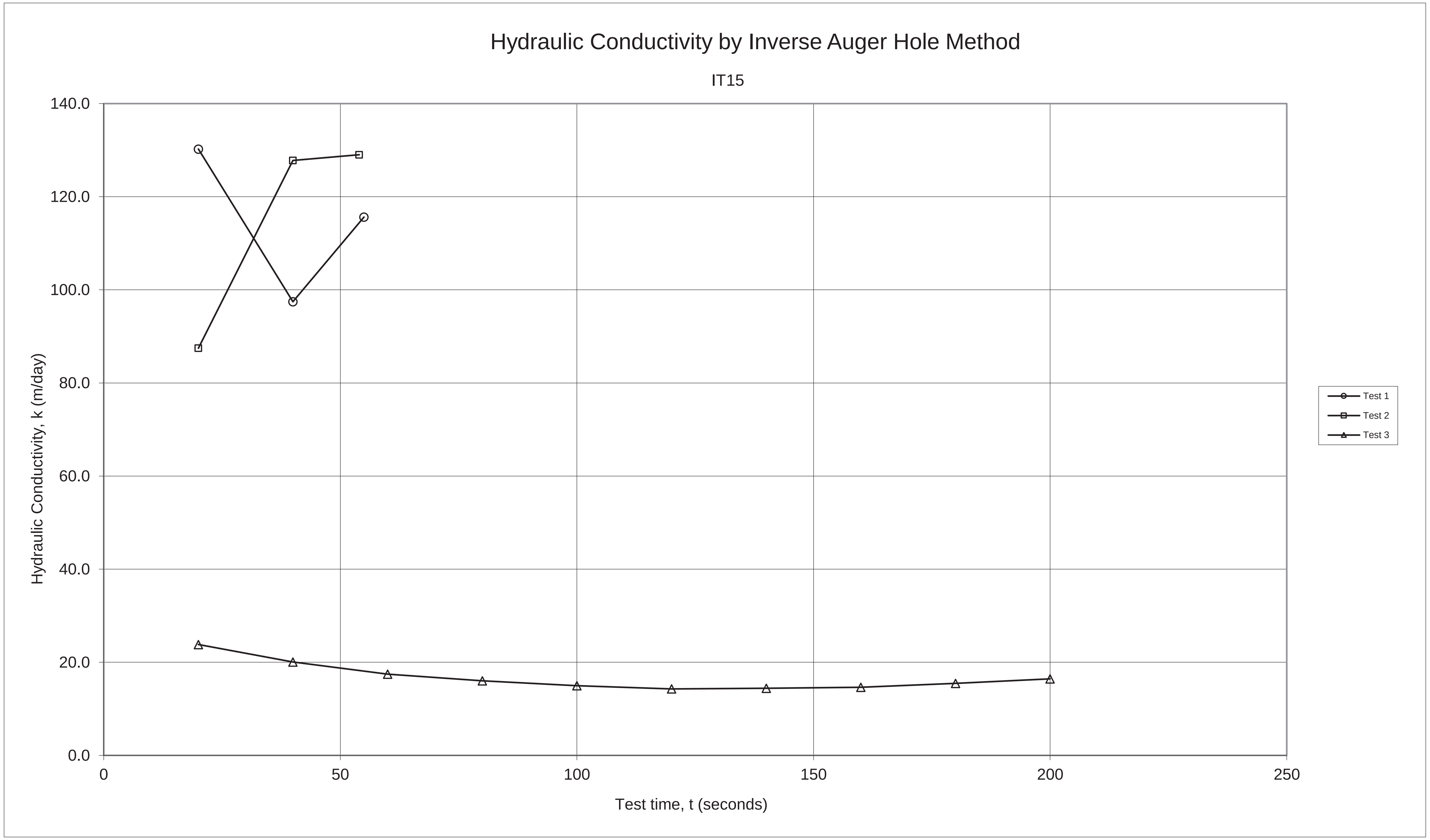
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.401	0.599		
20	0.86	0.14	1.5E-03	130.2
40	0.939	0.061	1.1E-03	97.4
55	0.999	0.001	1.3E-03	115.6
		AVERAGE	1.3E-03	114.4

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.209	0.791		
20	0.692	0.308	1.0E-03	87.5
40	0.964	0.036	1.5E-03	127.8
54	1	0	1.5E-03	129.0
		AVERAGE	1.3E-03	114.8

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.857	0.143		
20	0.893	0.107	2.8E-04	23.8
40	0.913	0.087	2.3E-04	20.1
60	0.926	0.074	2.0E-04	17.5
80	0.937	0.063	1.9E-04	16.0
100	0.946	0.054	1.7E-04	15.0
120	0.954	0.046	1.7E-04	14.3
140	0.964	0.036	1.7E-04	14.4
160	0.973	0.027	1.7E-04	14.6
180	0.983	0.017	1.8E-04	15.5
200	0.992	0.008	1.9E-04	16.4
		AVERAGE	1.9E-04	16.8



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Hydraulic Conductivity Calculation - Inverse Auger Hole Method

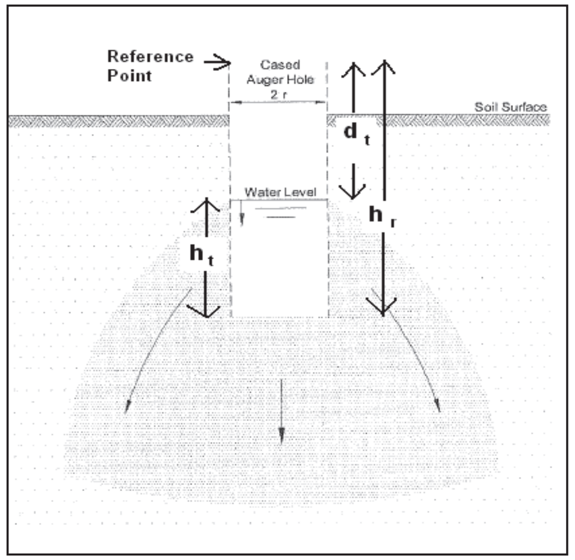
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT16
Test Depth:	1.45 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r\,\frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

	Required input
	Calculated field
	Comment field
	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	1.45	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

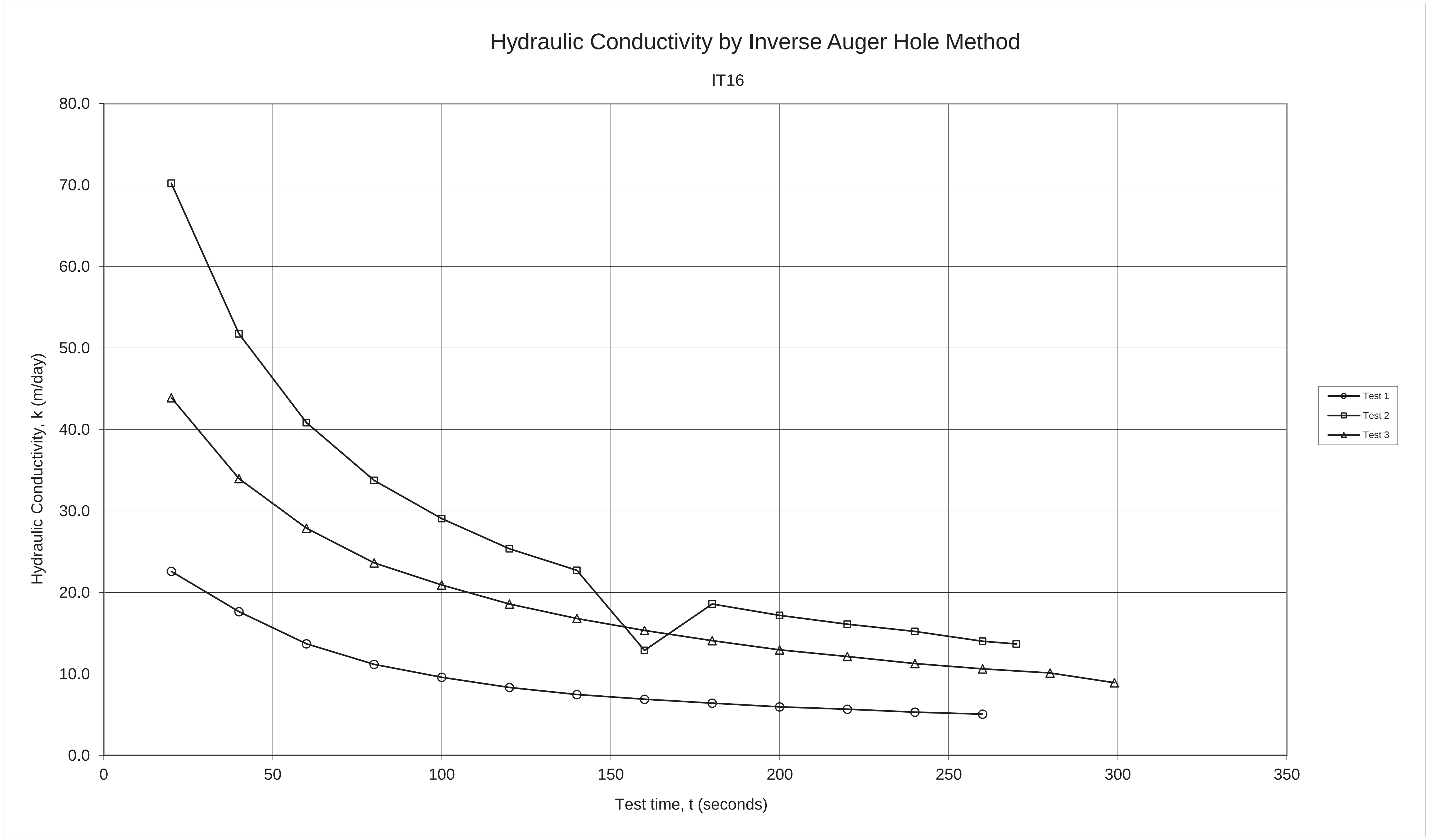
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.928	0.522		
20	1.041	0.409	2.6E-04	22.6
40	1.094	0.356	2.0E-04	17.7
60	1.116	0.334	1.6E-04	13.7
80	1.129	0.321	1.3E-04	11.2
100	1.14	0.31	1.1E-04	9.6
120	1.147	0.303	9.6E-05	8.3
140	1.155	0.295	8.7E-05	7.5
160	1.164	0.286	8.0E-05	6.9
180	1.172	0.278	7.4E-05	6.4
200	1.178	0.272	6.9E-05	6.0
220	1.186	0.264	6.6E-05	5.7
240	1.19	0.26	6.1E-05	5.3
260	1.196	0.254	5.9E-05	5.1
		AVERAGE	1.1E-04	9.7

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.478	0.972		
20	0.99	0.46	8.1E-04	70.2
40	1.13	0.32	6.0E-04	51.7
60	1.191	0.259	4.7E-04	40.8
80	1.225	0.225	3.9E-04	33.8
100	1.25	0.2	3.4E-04	29.1
120	1.265	0.185	2.9E-04	25.4
140	1.279	0.171	2.6E-04	22.7
160	1.1286	0.3214	1.5E-04	12.9
180	1.295	0.155	2.2E-04	18.6
200	1.303	0.147	2.0E-04	17.2
220	1.312	0.138	1.9E-04	16.1
240	1.321	0.129	1.8E-04	15.2
260	1.32	0.13	1.6E-04	14.0
270	1.324	0.126	1.6E-04	13.7
		AVERAGE	3.2E-04	27.2

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.799	0.651		
20	1.044	0.406	5.1E-04	43.9
40	1.138	0.312	3.9E-04	34.0
60	1.188	0.262	3.2E-04	27.9
80	1.218	0.232	2.7E-04	23.6
100	1.243	0.207	2.4E-04	20.9
120	1.259	0.191	2.2E-04	18.6
140	1.272	0.178	1.9E-04	16.8
160	1.282	0.168	1.8E-04	15.3
180	1.29	0.16	1.6E-04	14.1
200	1.295	0.155	1.5E-04	12.9
220	1.302	0.148	1.4E-04	12.1
240	1.305	0.145	1.3E-04	11.3
260	1.31	0.14	1.2E-04	10.6
280	1.316	0.134	1.2E-04	10.1
299	1.302	0.148	1.0E-04	8.9
		AVERAGE	2.2E-04	18.7



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Hydraulic Conductivity Calculation - Inverse Auger Hole Method

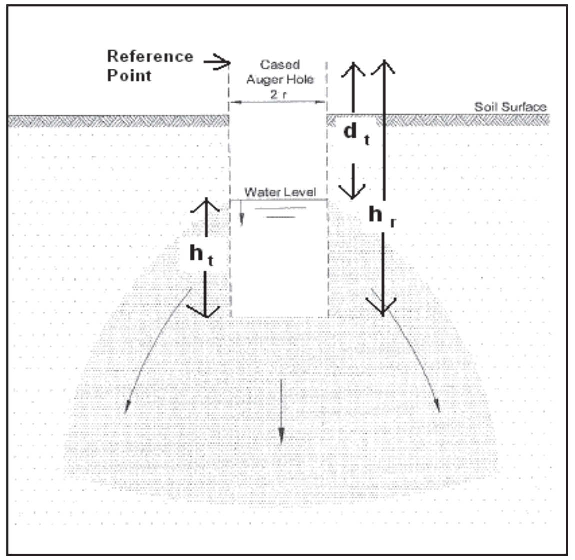
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT17
Test Depth:	2.80 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

(blue)	Required input
(green)	Calculated field
(orange)	Comment field
(crossed)	Field not used
(yellow)	Fixed field

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

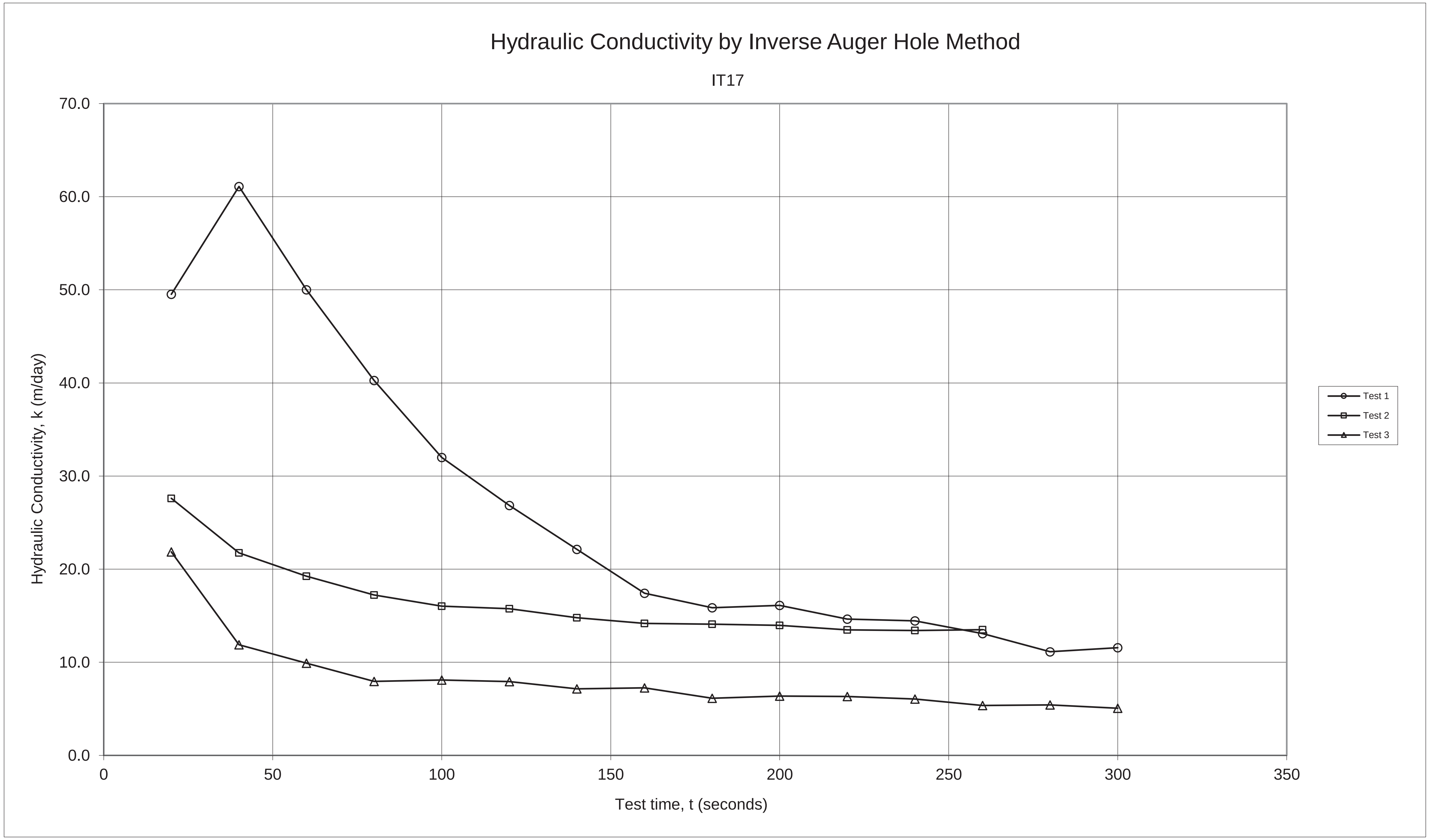
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.342	0.458		
20	2.534	0.266	5.7E-04	49.5
40	2.686	0.114	7.1E-04	61.1
60	2.72	0.08	5.8E-04	50.0
80	2.731	0.069	4.7E-04	40.3
100	2.73	0.07	3.7E-04	32.0
120	2.731	0.069	3.1E-04	26.8
140	2.725	0.075	2.6E-04	22.1
160	2.708	0.092	2.0E-04	17.4
180	2.712	0.088	1.8E-04	15.9
200	2.731	0.069	1.9E-04	16.1
220	2.731	0.069	1.7E-04	14.6
240	2.742	0.058	1.7E-04	14.5
260	2.739	0.061	1.5E-04	13.1
280	2.726	0.074	1.3E-04	11.1
300	2.742	0.058	1.3E-04	11.6
		AVERAGE	3.1E-04	26.4

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.673	0.127		
20	2.71	0.09	3.2E-04	27.6
40	2.727	0.073	2.5E-04	21.8
60	2.74	0.06	2.2E-04	19.2
80	2.749	0.051	2.0E-04	17.2
100	2.757	0.043	1.9E-04	16.0
120	2.766	0.034	1.8E-04	15.7
140	2.771	0.029	1.7E-04	14.8
160	2.776	0.024	1.6E-04	14.2
180	2.782	0.018	1.6E-04	14.1
200	2.787	0.013	1.6E-04	14.0
220	2.79	0.01	1.6E-04	13.5
240	2.794	0.006	1.6E-04	13.4
260	2.798	0.002	1.6E-04	13.5
		AVERAGE	1.9E-04	16.5

Test 3

t (s)		h_t (m)	K (m/s)	K (m/day)
0	2.758	0.042		
20	2.771	0.029	2.5E-04	21.9
40	2.772	0.028	1.4E-04	11.9
60	2.775	0.025	1.1E-04	9.9
80	2.776	0.024	9.2E-05	7.9
100	2.78	0.02	9.4E-05	8.1
120	2.783	0.017	9.2E-05	7.9
140	2.784	0.016	8.3E-05	7.2
160	2.787	0.013	8.4E-05	7.2
180	2.786	0.014	7.1E-05	6.1
200	2.789	0.011	7.4E-05	6.4
220	2.791	0.009	7.3E-05	6.3
240	2.792	0.008	7.0E-05	6.1
260	2.791	0.009	6.2E-05	5.4
280	2.793	0.007	6.3E-05	5.4
300	2.793	0.007	5.9E-05	5.1
		AVERAGE	9.5E-05	8.2



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Hydraulic Conductivity Calculation - Inverse Auger Hole Method

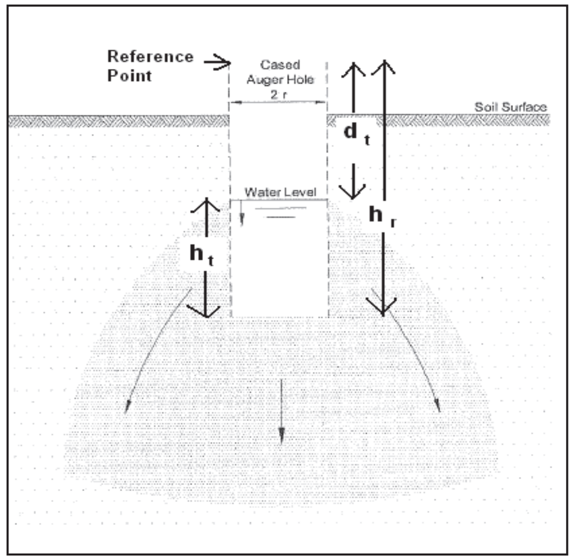
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT18
Test Depth:	2.80 m

Spreadsheet author: ORW 17-Oct-09

$$K = 1.15r\frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

Required input	
Calculated field	
Comment field	
Field not used	
Fixed field	

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

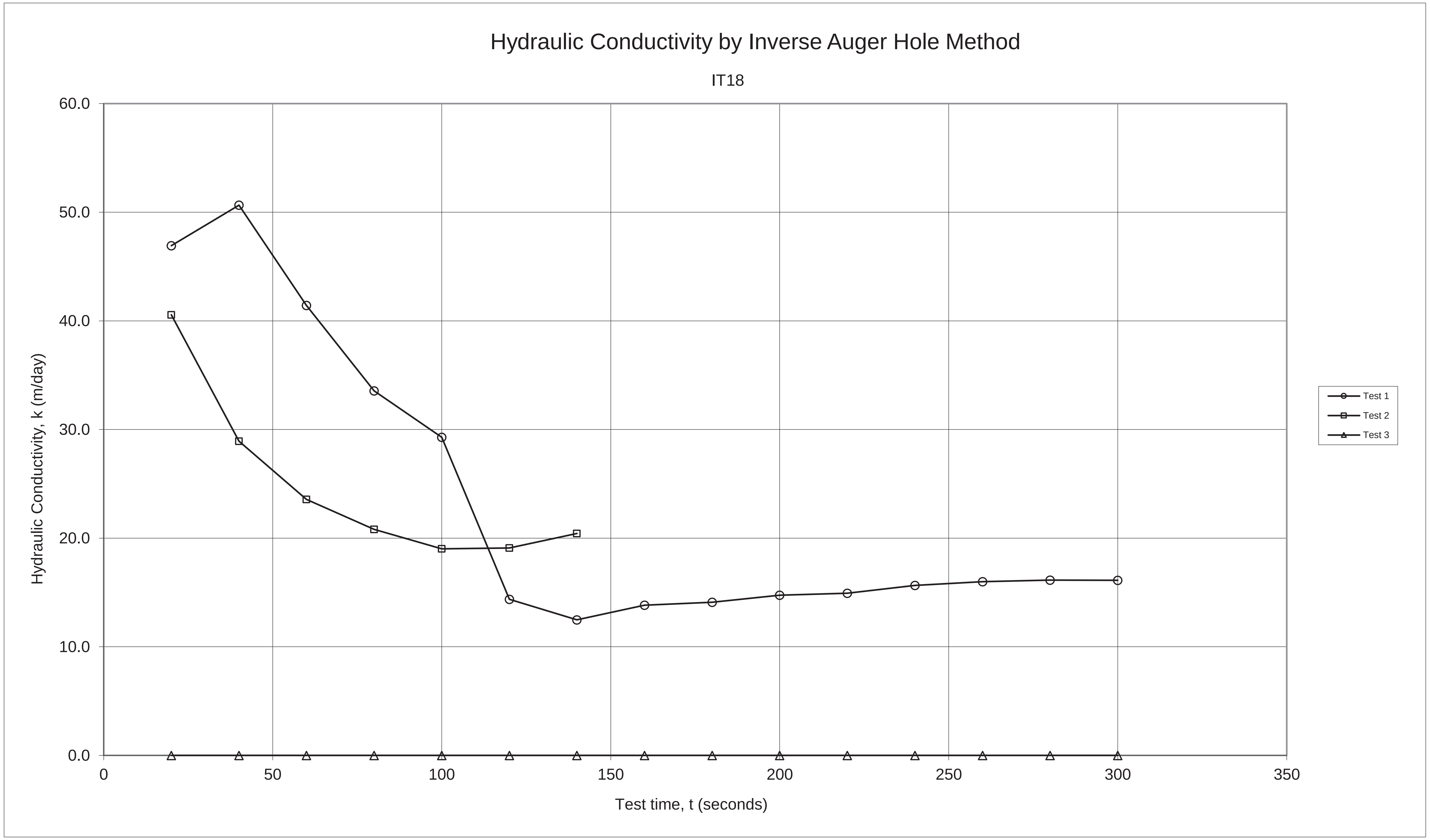
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.418	0.382		
20	2.573	0.227	5.4E-04	46.9
40	2.68	0.12	5.9E-04	50.6
60	2.71	0.09	4.8E-04	41.4
80	2.721	0.079	3.9E-04	33.6
100	2.733	0.067	3.4E-04	29.3
120	2.656	0.144	1.7E-04	14.4
140	2.658	0.142	1.4E-04	12.5
160	2.693	0.107	1.6E-04	13.8
180	2.713	0.087	1.6E-04	14.1
200	2.734	0.066	1.7E-04	14.8
220	2.748	0.052	1.7E-04	14.9
240	2.764	0.036	1.8E-04	15.6
260	2.775	0.025	1.9E-04	16.0
280	2.783	0.017	1.9E-04	16.1
300	2.789	0.011	1.9E-04	16.1
		AVERAGE	2.7E-04	23.3

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.72	0.08		
20	2.755	0.045	4.7E-04	40.6
40	2.766	0.034	3.3E-04	28.9
60	2.773	0.027	2.7E-04	23.6
80	2.779	0.021	2.4E-04	20.8
100	2.784	0.016	2.2E-04	19.0
120	2.791	0.009	2.2E-04	19.1
140	2.799	0.001	2.4E-04	20.4
		AVERAGE	2.9E-04	24.6

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0				
20				
40				
60				
80				
100				
120				
140				
160				
180				
200				
220				
240				
260				
280				
300				
		AVERAGE	#DIV/0!	#DIV/0!



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Hydraulic Conductivity Calculation - Inverse Auger Hole Method

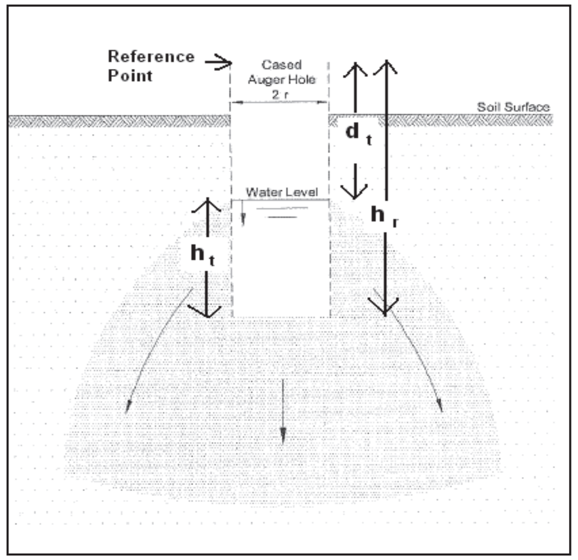
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT19
Test Depth:	2.70 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

Required input	
Calculated field	
Comment field	
Field not used	
Fixed field	

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.7	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

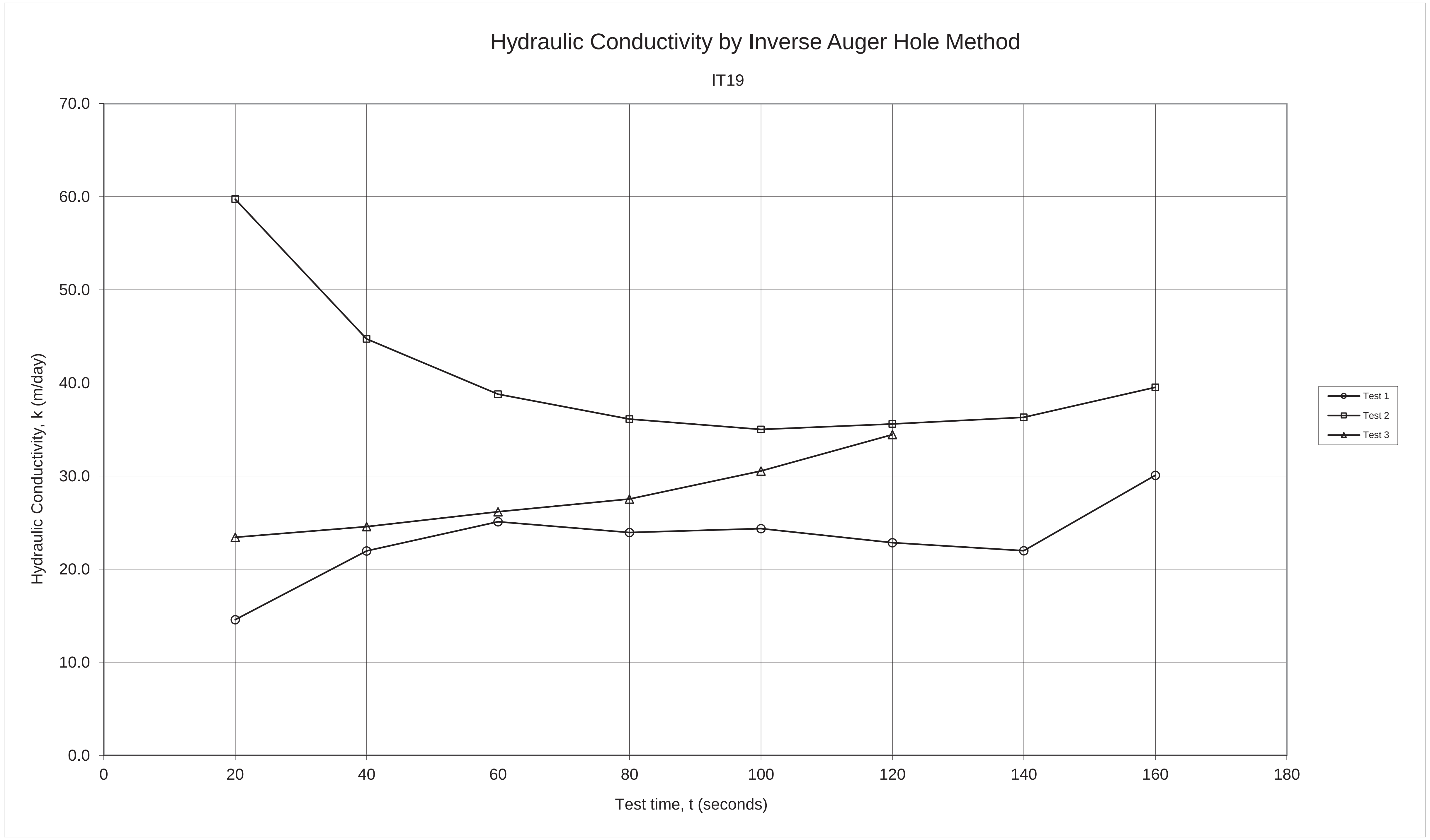
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.335	0.365		
20	2.389	0.311	1.7E-04	14.6
40	2.476	0.224	2.5E-04	22.0
60	2.544	0.156	2.9E-04	25.1
80	2.578	0.122	2.8E-04	23.9
100	2.612	0.088	2.8E-04	24.4
120	2.628	0.072	2.6E-04	22.8
140	2.643	0.057	2.5E-04	22.0
160	2.69	0.01	3.5E-04	30.1
		AVERAGE	2.7E-04	23.1

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.852	0.848		
20	2.252	0.448	6.9E-04	59.7
40	2.376	0.324	5.2E-04	44.7
60	2.46	0.24	4.5E-04	38.8
80	2.526	0.174	4.2E-04	36.1
100	2.579	0.121	4.1E-04	35.0
120	2.626	0.074	4.1E-04	35.6
140	2.659	0.041	4.2E-04	36.3
160	2.689	0.011	4.6E-04	39.5
		AVERAGE	4.7E-04	40.7

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.214	0.486		
20	2.323	0.377	2.7E-04	23.4
40	2.416	0.284	2.8E-04	24.6
60	2.496	0.204	3.0E-04	26.2
80	2.559	0.141	3.2E-04	27.5
100	2.617	0.083	3.5E-04	30.5
120	2.662	0.038	4.0E-04	34.4
		AVERAGE	3.2E-04	27.8



https://galtgeo.sharepoint.com/sites/WAE221033/Shared Documents/02 Qube Infilt Testing/08 Analysis/20231006 - Permeability Inverse Auger Spreadsheets MDS-KS/WAE221033-02 IT Results Combined

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

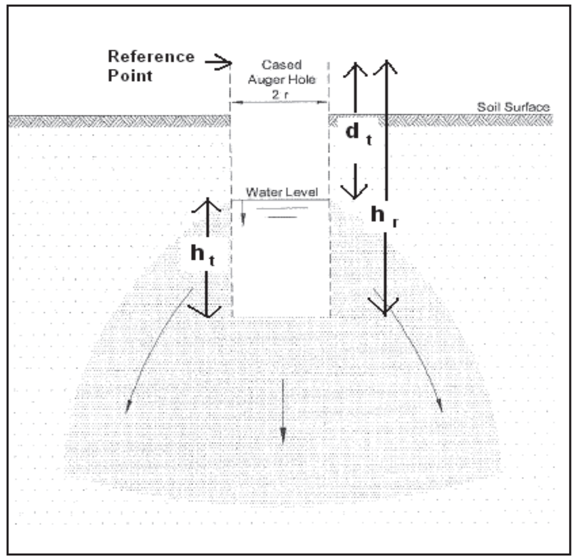
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT19
Test Depth:	2.80 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r\,\frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

(blue)	Required input
(green)	Calculated field
(orange)	Comment field
(crossed)	Field not used
(yellow)	Fixed field

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.8	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

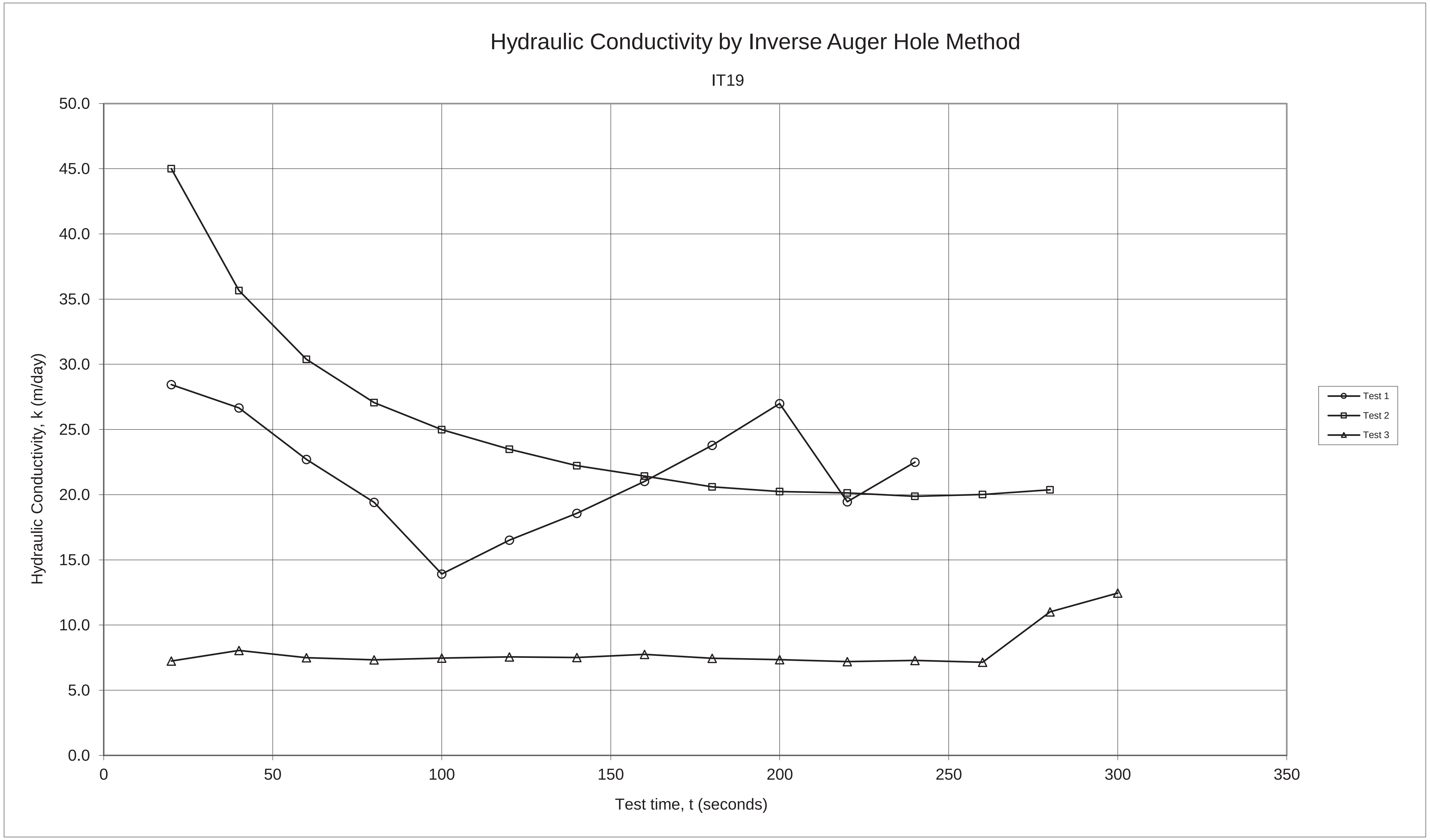
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.283	0.517		
20	2.42	0.38	3.3E-04	28.4
40	2.511	0.289	3.1E-04	26.7
60	2.555	0.245	2.6E-04	22.7
80	2.58	0.22	2.2E-04	19.4
100	2.559	0.241	1.6E-04	13.9
120	2.628	0.172	1.9E-04	16.5
140	2.681	0.119	2.1E-04	18.6
160	2.727	0.073	2.4E-04	21.0
180	2.763	0.037	2.8E-04	23.8
200	2.789	0.011	3.1E-04	27.0
220	2.763	0.037	2.3E-04	19.5
240	2.789	0.011	2.6E-04	22.5
		AVERAGE	2.5E-04	21.7

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.604	1.196		
20	2.056	0.744	5.2E-04	45.0
40	2.238	0.562	4.1E-04	35.7
60	2.346	0.454	3.5E-04	30.4
80	2.423	0.377	3.1E-04	27.1
100	2.486	0.314	2.9E-04	25.0
120	2.537	0.263	2.7E-04	23.5
140	2.577	0.223	2.6E-04	22.2
160	2.614	0.186	2.5E-04	21.4
180	2.642	0.158	2.4E-04	20.6
200	2.671	0.129	2.3E-04	20.2
220	2.698	0.102	2.3E-04	20.1
240	2.718	0.082	2.3E-04	19.9
260	2.739	0.061	2.3E-04	20.0
280	2.758	0.042	2.4E-04	20.4
		AVERAGE	2.9E-04	25.1

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.6	0.2		
20	2.616	0.184	8.4E-05	7.2
40	2.634	0.166	9.3E-05	8.1
60	2.646	0.154	8.7E-05	7.5
80	2.658	0.142	8.5E-05	7.3
100	2.671	0.129	8.6E-05	7.5
120	2.683	0.117	8.7E-05	7.6
140	2.693	0.107	8.7E-05	7.5
160	2.705	0.095	9.0E-05	7.7
180	2.711	0.089	8.6E-05	7.5
200	2.718	0.082	8.5E-05	7.3
220	2.724	0.076	8.3E-05	7.2
240	2.732	0.068	8.4E-05	7.3
260	2.737	0.063	8.3E-05	7.1
280	2.777	0.023	1.3E-04	11.0
300	2.79	0.01	1.4E-04	12.5
		AVERAGE	9.3E-05	8.0



https://galtgeo.sharepoint.com/sites/WAE221033/Shared Documents/02 Qube Infilt Testing/08 Analysis/20231006 - Permeability Inverse Auger Spreadsheets MDS-KS/WAE221033-02 IT Results Combined

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

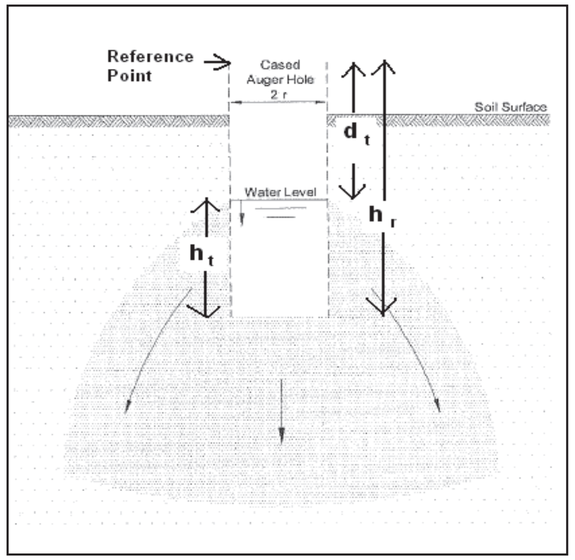
Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09		

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT21
Test Depth:	2.90 m

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

Required input	
Calculated field	
Comment field	
Field not used	
Fixed field	

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.9	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

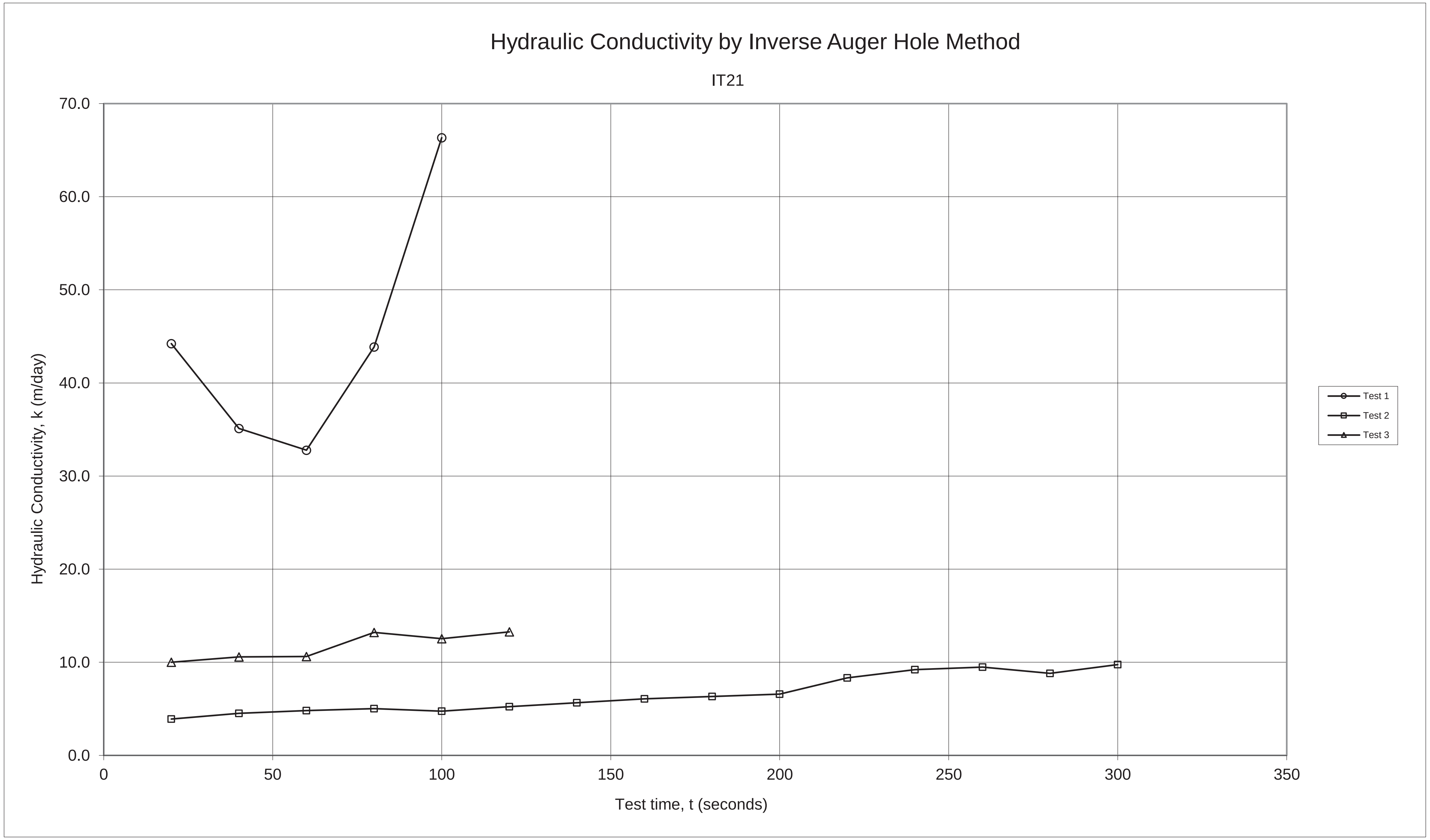
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	1.963	0.937		
20	2.314	0.586	5.1E-04	44.2
40	2.457	0.443	4.1E-04	35.1
60	2.574	0.326	3.8E-04	32.8
80	2.765	0.135	5.1E-04	43.9
100	2.891	0.009	7.7E-04	66.3
		AVERAGE	5.1E-04	44.5

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.821	0.079		
20	2.825	0.075	4.5E-05	3.9
40	2.83	0.07	5.2E-05	4.5
60	2.835	0.065	5.6E-05	4.8
80	2.84	0.06	5.8E-05	5.0
100	2.843	0.057	5.5E-05	4.7
120	2.849	0.051	6.0E-05	5.2
140	2.855	0.045	6.5E-05	5.7
160	2.861	0.039	7.0E-05	6.1
180	2.866	0.034	7.3E-05	6.3
200	2.871	0.029	7.6E-05	6.6
220	2.883	0.017	9.6E-05	8.3
240	2.89	0.01	1.1E-04	9.2
260	2.894	0.006	1.1E-04	9.5
280	2.894	0.006	1.0E-04	8.8
300	2.9	0	1.1E-04	9.8
		AVERAGE	7.6E-05	6.6

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.851	0.049		
20	2.858	0.042	1.2E-04	10.0
40	2.865	0.035	1.2E-04	10.6
60	2.871	0.029	1.2E-04	10.6
80	2.881	0.019	1.5E-04	13.2
100	2.885	0.015	1.5E-04	12.5
120	2.891	0.009	1.5E-04	13.3
		AVERAGE	1.4E-04	11.7



Hydraulic Conductivity by Inverse Auger Hole Method
IT21
Hydraulic Conductivity, k (m/day)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
50
100
150
200
250
300
350
Test time, t (seconds)
Test 1
Test 2
Test 3

Hydraulic Conductivity Calculation - Inverse Auger Hole Method

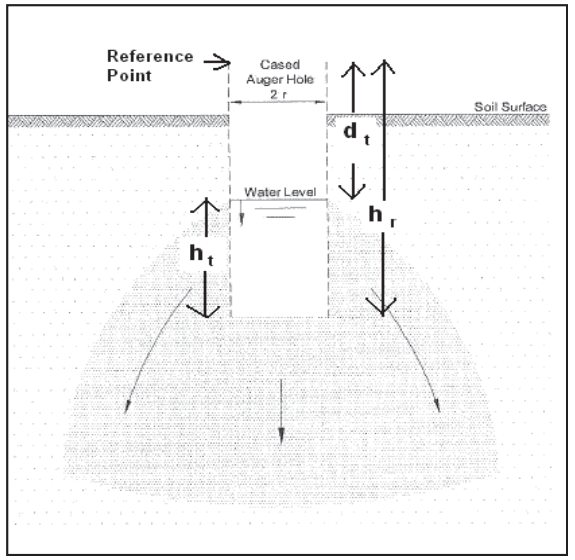
Galt Geotechnics

Job No:	WAE221033-02
Client:	QUBE Property Group
Project:	Proposed Drainage Swa
Location:	Precinct 8, East Wanne
Calc by:	MDS
BH Name:	IT22
Test Depth:	2.90 m

Spreadsheet author:	ORW	17-Oct-09

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

(blue)	Required input
(green)	Calculated field
(orange)	Comment field
(crossed)	Field not used
(yellow)	Fixed field

Parameter	Description	Value	Units
K	Hydraulic Conductivity		m/s
r	radius of test hole	0.045	m
t	time since start of measurement		s
h_r	reference point height above base	2.9	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

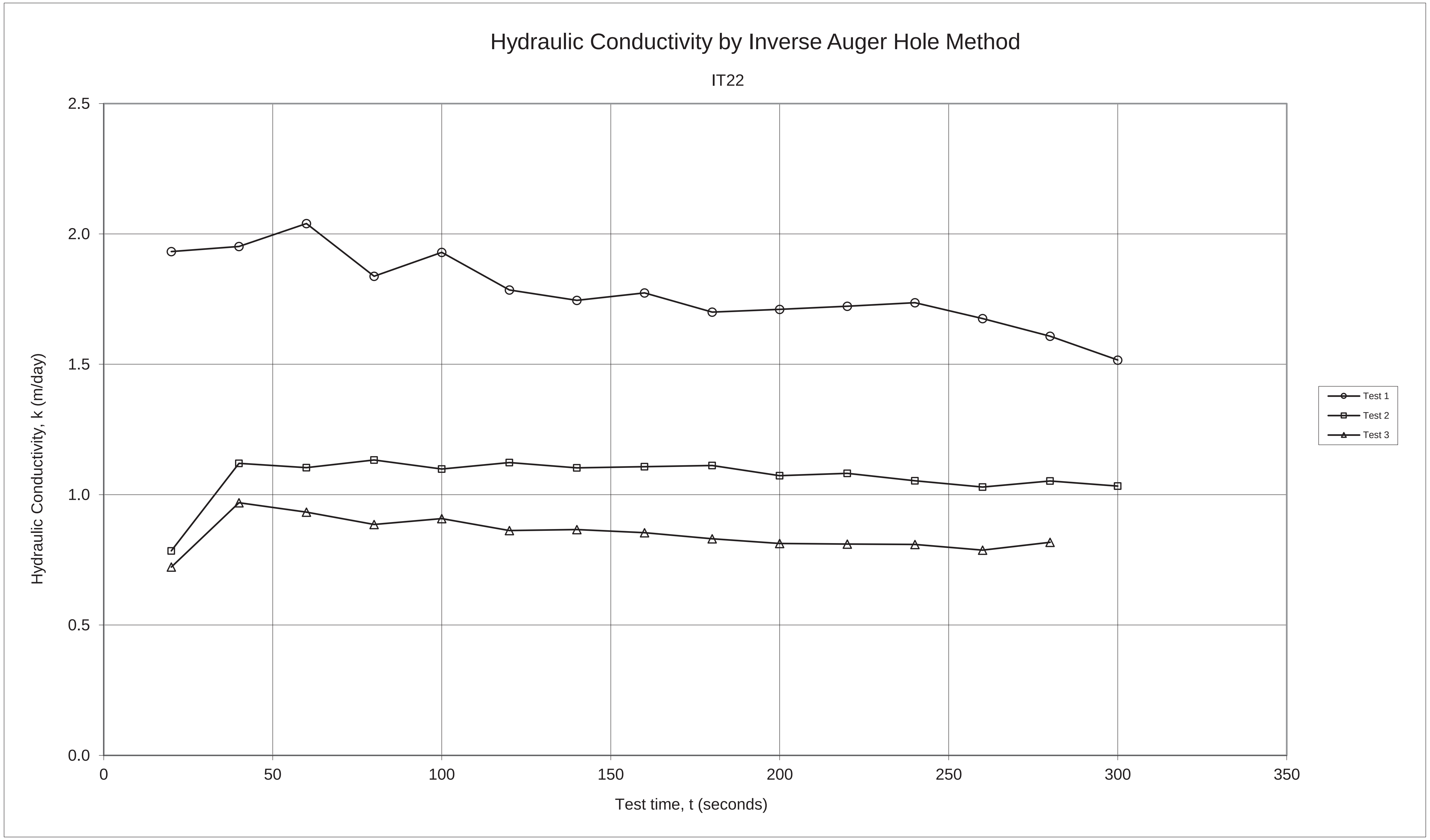
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.415	0.485		
20	2.425	0.475	2.2E-05	1.9
40	2.435	0.465	2.3E-05	2.0
60	2.446	0.454	2.4E-05	2.0
80	2.452	0.448	2.1E-05	1.8
100	2.463	0.437	2.2E-05	1.9
120	2.468	0.432	2.1E-05	1.8
140	2.475	0.425	2.0E-05	1.7
160	2.484	0.416	2.1E-05	1.8
180	2.489	0.411	2.0E-05	1.7
200	2.497	0.403	2.0E-05	1.7
220	2.505	0.395	2.0E-05	1.7
240	2.513	0.387	2.0E-05	1.7
260	2.517	0.383	1.9E-05	1.7
280	2.52	0.38	1.9E-05	1.6
300	2.521	0.379	1.8E-05	1.5
		AVERAGE	2.1E-05	1.8

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.177	0.723		
20	2.183	0.717	9.1E-06	0.8
40	2.194	0.706	1.3E-05	1.1
60	2.202	0.698	1.3E-05	1.1
80	2.211	0.689	1.3E-05	1.1
100	2.218	0.682	1.3E-05	1.1
120	2.227	0.673	1.3E-05	1.1
140	2.234	0.666	1.3E-05	1.1
160	2.242	0.658	1.3E-05	1.1
180	2.25	0.65	1.3E-05	1.1
200	2.255	0.645	1.2E-05	1.1
220	2.263	0.637	1.3E-05	1.1
240	2.268	0.632	1.2E-05	1.1
260	2.273	0.627	1.2E-05	1.0
280	2.282	0.618	1.2E-05	1.1
300	2.287	0.613	1.2E-05	1.0
		AVERAGE	1.2E-05	1.1

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	2.113	0.787		
20	2.119	0.781	8.4E-06	0.7
40	2.129	0.771	1.1E-05	1.0
60	2.136	0.764	1.1E-05	0.9
80	2.142	0.758	1.0E-05	0.9
100	2.15	0.75	1.1E-05	0.9
120	2.155	0.745	1.0E-05	0.9
140	2.162	0.738	1.0E-05	0.9
160	2.168	0.732	9.9E-06	0.9
180	2.173	0.727	9.6E-06	0.8
200	2.178	0.722	9.4E-06	0.8
220	2.184	0.716	9.4E-06	0.8
240	2.19	0.71	9.4E-06	0.8
260	2.194	0.706	9.1E-06	0.8
280	2.203	0.697	9.5E-06	0.8
		AVERAGE	9.8E-06	0.8


Hydraulic Conductivity by Inverse Auger Hole Method
IT22
Hydraulic Conductivity, k (m/day)
2.5
2.0
1.5
1.0
0.5
0.0
0
50
100
150
200
250
300
350
Test time, t (seconds)
Test 1
Test 2
Test 3

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ATTACHMENT D

Understanding Your Report

UNDERSTANDING YOUR REPORT

GALT FORM PMP11 Rev4

1. EXPECTATIONS OF THE REPORT

This document has been prepared to clarify what is and is not provided in your report. It is intended to inform you of what your realistic expectations of this report should be and how to manage your risks associated with the conditions on site.

Geotechnical engineering and environmental science are less exact than other engineering and scientific disciplines. We include this information to help you understand where our responsibilities begin and end. You should read and understand this information. Please contact us if you do not understand the report or this explanation. We have extensive experience in a wide variety of projects and we can help you to manage your risk.

2. THIS REPORT RELATES TO PROJECT-SPECIFIC CONDITIONS

This report was developed for a unique set of project-specific conditions to meet the needs of the nominated client. It took into account the following:

- the project objectives as we understood them and as described in this report;
- the specific site mentioned in this report; and
- the current and proposed development at the site.

It should not be used for any purpose other than that indicated in the report. You should not rely on this report if any of the following conditions apply:

- the report was not written for you;
- the report was not written for the site specific to your development;
- the report was not written for your project (including a development at the correct site but other than that listed in the report); or
- the report was written before significant changes occurred at the site (such as a development or a change in ground conditions).

You should always inform us of changes in the proposed project (including minor changes) and request an assessment of their impact.

Where we are not informed of developments relevant to your report, we cannot be held responsible or liable for problems that may arise as a consequence.

Where design is to be carried out by others using information provided by us, we recommend that we be involved in the design process by being engaged for consultation with other members of the project team. Furthermore, we recommend that we be able to review work produced by other members of the project team that relies on information provided in our report.

3. DATA PROVIDED BY THIRD PARTIES

Where data is provided by third parties, it will be identified as such in our reports. We necessarily rely on the completeness and accuracy of data provided by third parties in order to draw conclusions presented in our reports. We are not responsible for omissions, incomplete or inaccurate data associated with third party data, including where we have been requested to provide advice in relation to field investigation data provided by third parties.

4. SOIL LOGS

Our reports often include logs of intrusive and non-intrusive investigation techniques prepared by Galt. These logs are based on our interpretation of field data and laboratory results. The logs should only be read in conjunction with the report they were issued with and should not be re-drawn for inclusion in other documents not prepared by us.

5. THIRD PARTY RELIANCE

We have prepared this report for use by the client. This report must be regarded as confidential to the client and the client's professional advisors. We do not accept any responsibility for contents of this document from any party other than the nominated client. We take no responsibility for any damages suffered by a third party because of any decisions or actions they may make based on this report. Any reliance or decisions made by a third party based on this report are the responsibility of the third party and not of us.

6. CHANGE IN SUBSURFACE CONDITIONS

The recommendations in this report are based on the ground conditions that existed at the time when the study was undertaken. Changes in ground conditions can occur in numerous ways including anthropogenic events (such as construction or contaminating activities on or adjacent to the site) or natural events (such as floods, groundwater fluctuations or earthquakes). We should be consulted prior to use of this report so that we can comment on its reliability. It is important to note that where ground conditions have changed, additional sampling, testing or analysis may be required to fully assess the changed conditions.

7. SUBSURFACE CONDITIONS DURING CONSTRUCTION

Practical constraints mean that we cannot know every minute detail about the subsurface conditions at a particular site. We use professional judgement to form an opinion about the subsurface conditions at the site. Some variation to our evaluated conditions is likely and significant variation is possible. Accordingly, our report should not be considered as final as it is developed from professional judgement and opinion.

The most effective means of dealing with unanticipated ground conditions is to engage us for construction support. We can only finalise our recommendations by observing actual subsurface conditions encountered during construction. We cannot accept liability for a report's recommendations if we cannot observe construction.

8. ENVIRONMENTAL AND GEOTECHNICAL ISSUES

Unless specifically mentioned otherwise in our report, environmental considerations are not addressed in geotechnical reports. Similarly, geotechnical issues are not addressed in environmental reports. The investigation techniques used for geotechnical investigations can differ from those used for environmental investigations. It is the client's responsibility to satisfy themselves that geotechnical and environmental considerations have been taken into account for the site.

Geotechnical advice presented in a Galt Environmental report has been provided by Galt Geotechnics under a sub-contract agreement. Similarly, environmental advice presented in a Galt Geotechnics report has been provided by Galt Environmental under a sub-contract agreement.

Unless specifically noted otherwise, no parties shall draw any inferences about the applicability of the Western Australian state government landfill levy from the contents of this document.

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