Characterisation of aquifer properties in data-scarce fractured rock aquifers – the Irish example

Taly Hunter Williams[1], Coran Kelly[2,1], Bruce Misstear[3], Kevin Motherway[4]

1. Geological Survey of Ireland, Dublin, Ireland
2. Tobin Consulting Engineers, Dublin, Ireland
3. Trinity College Dublin, Ireland
4. Environmental Protection Agency, Cork, Ireland

2422

25-29th September 2016
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Montpellier, France
CORUM CONFERENCE CENTER

IRISH AQUIFER PROPERTIES –

A REFERENCE MANUAL AND GUIDE

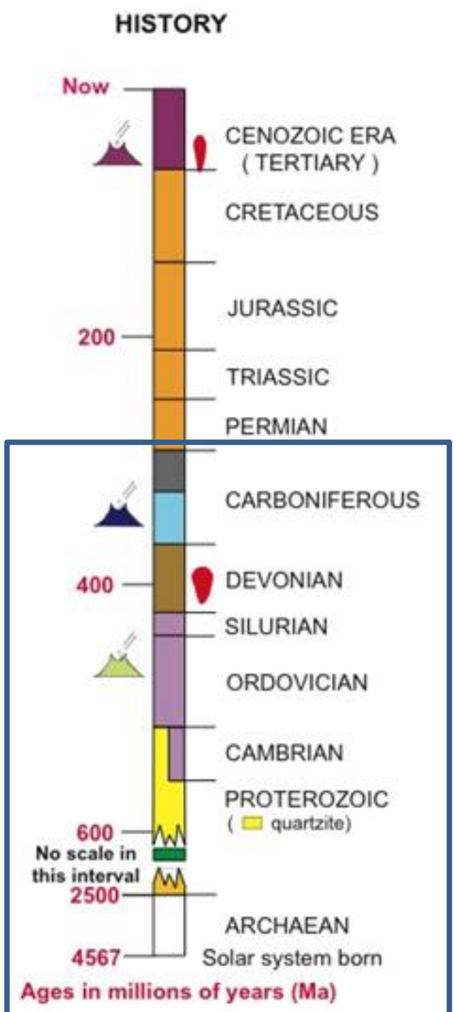
VERSION 1 MARCH 2015

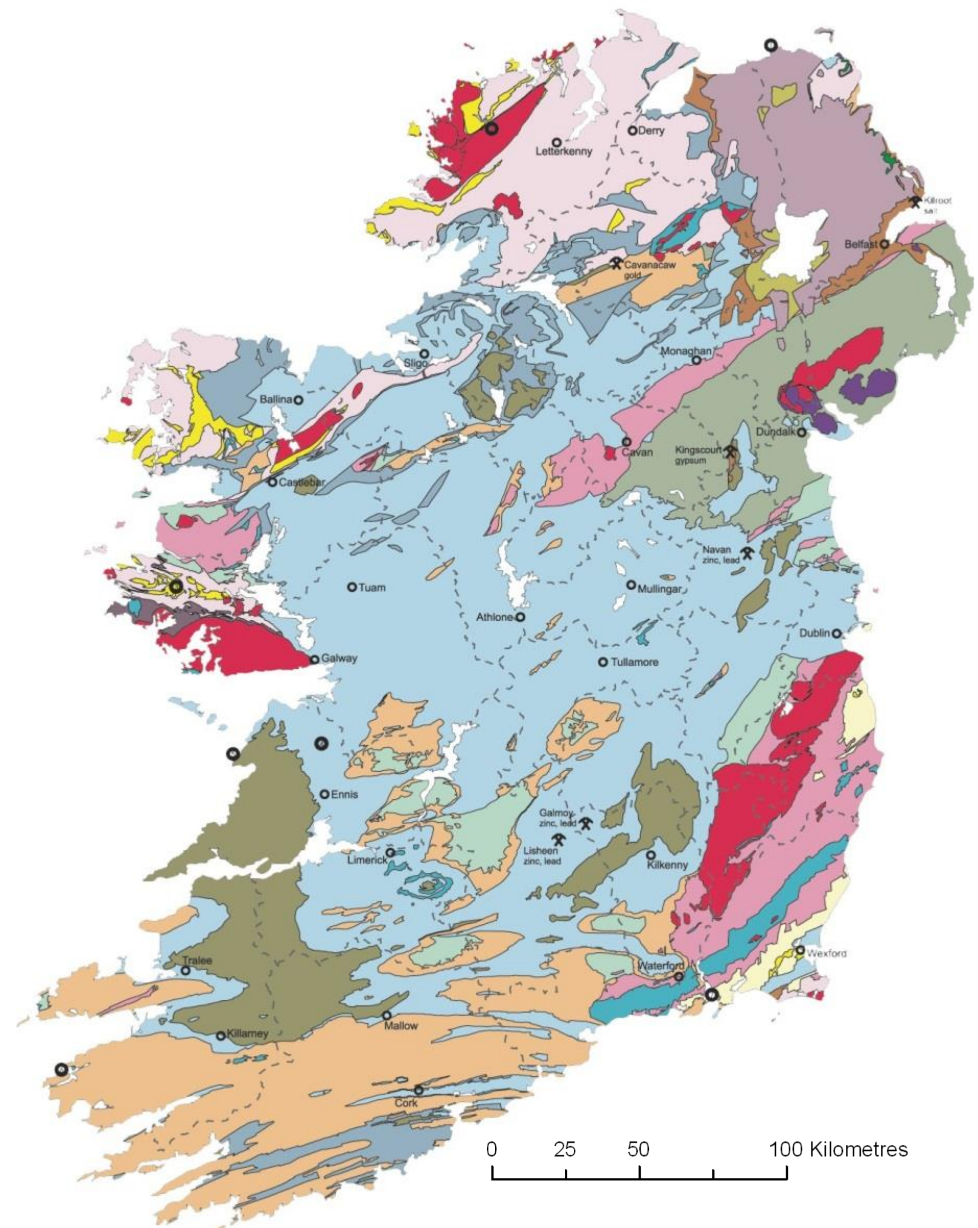
Environmental Protection Agency

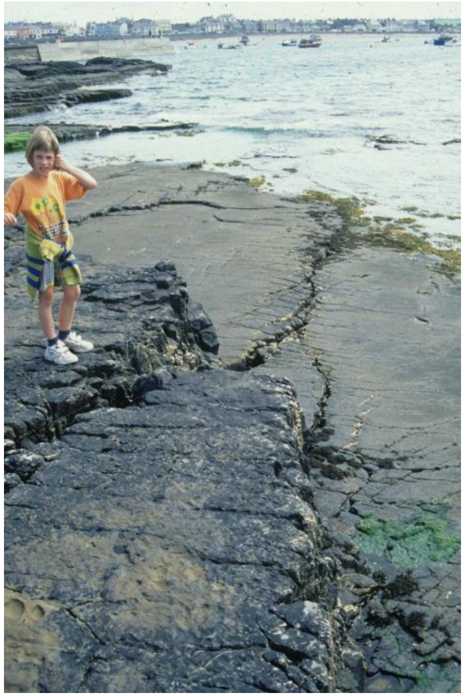
GSI
Geological Survey of Ireland

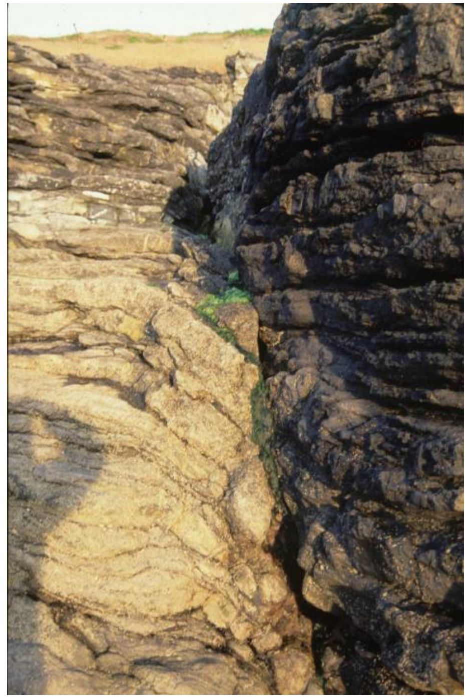
http://www.gsi.ie/programmes/groundwater/aquifer+classification

GEOLOGICAL AND HYDROGEOLOGICAL SETTING


HISTORY
Now
CENOZOIC ERA
(TERTIARY)
CRETACEOUS
JURASSIC
200
TRIASSIC
PERMIAN
CARBONIFEROUS
400
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PROTEROZOIC
(quartzite)
600
No scale in
this interval
2500
ARCHAEAN
4567
Solar system born
Ages in millions of years (Ma)


Derry
Letterkenny
Belfast
Cavanacaw gold
Sligo
Monaghan
Ballina
Dundalk
Cavan
Kingscourt gypsum
Castlebar
Navan zinc, lead
Tuam
Mullingar
Athlone
Dublin
Galway
Tullamore
Ennis
Galmoy zinc, lead
Lisheen zinc, lead
Limerick
Kilkenny
Tralee
Waterford
Wexford
Killarney
Mallow
Cork
0
25
50
100 Kilometres





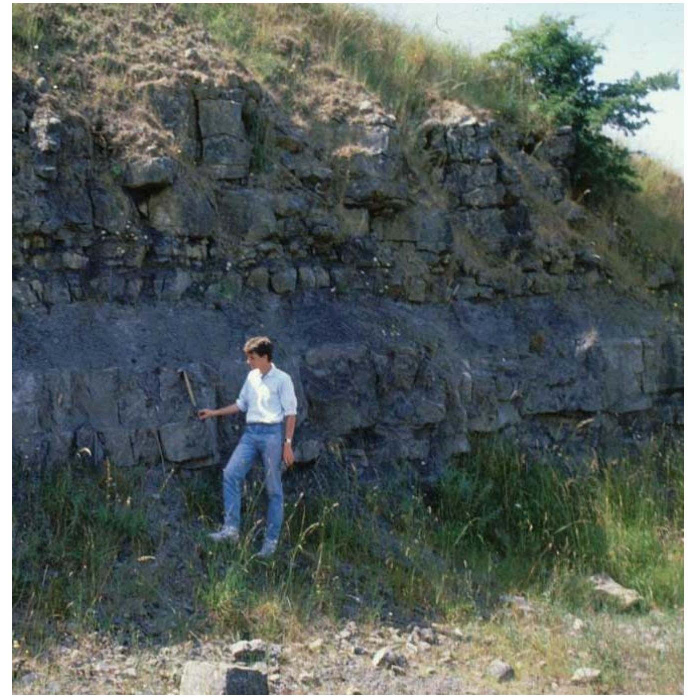


Photo credits: Donal Daly

GSI
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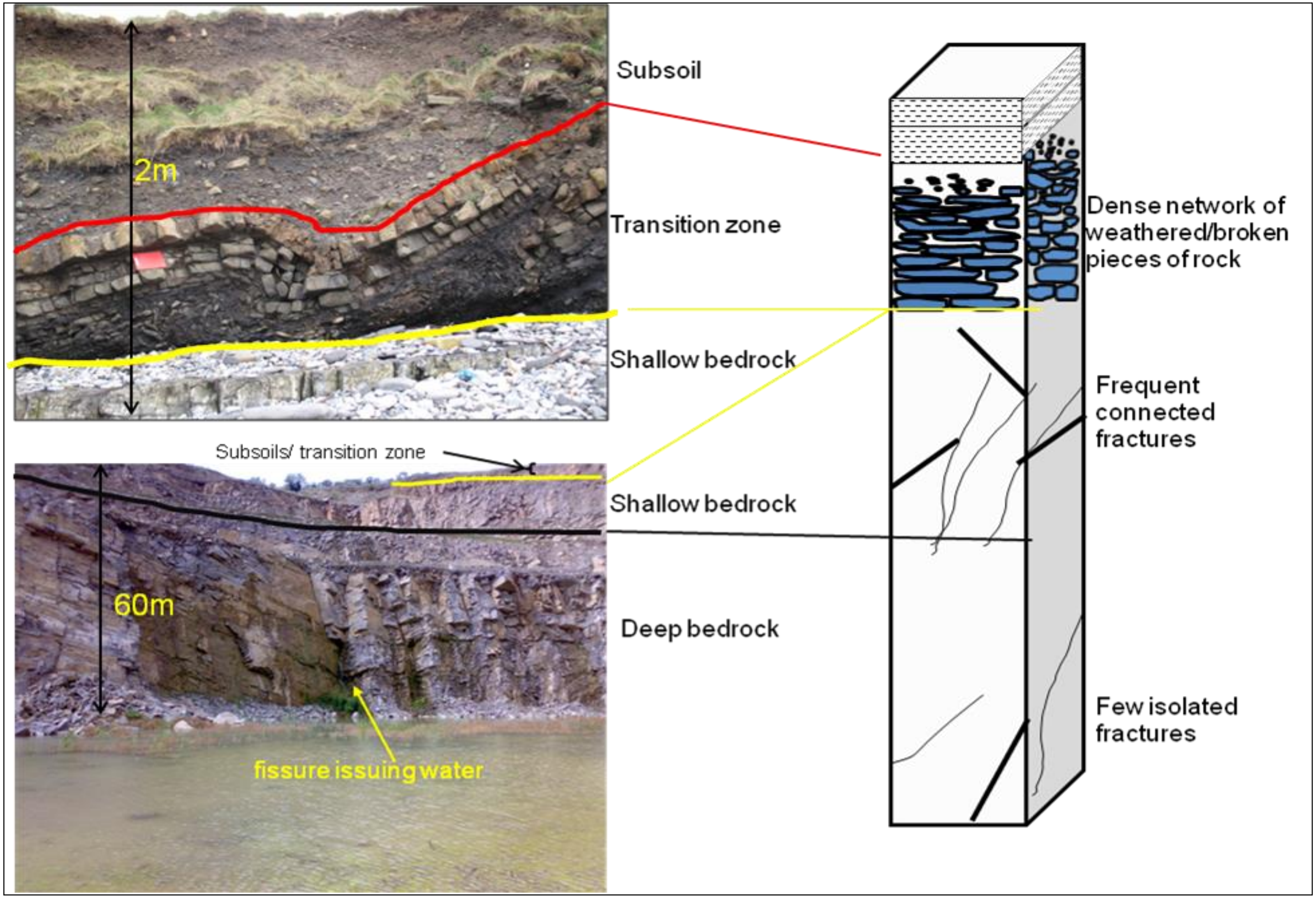
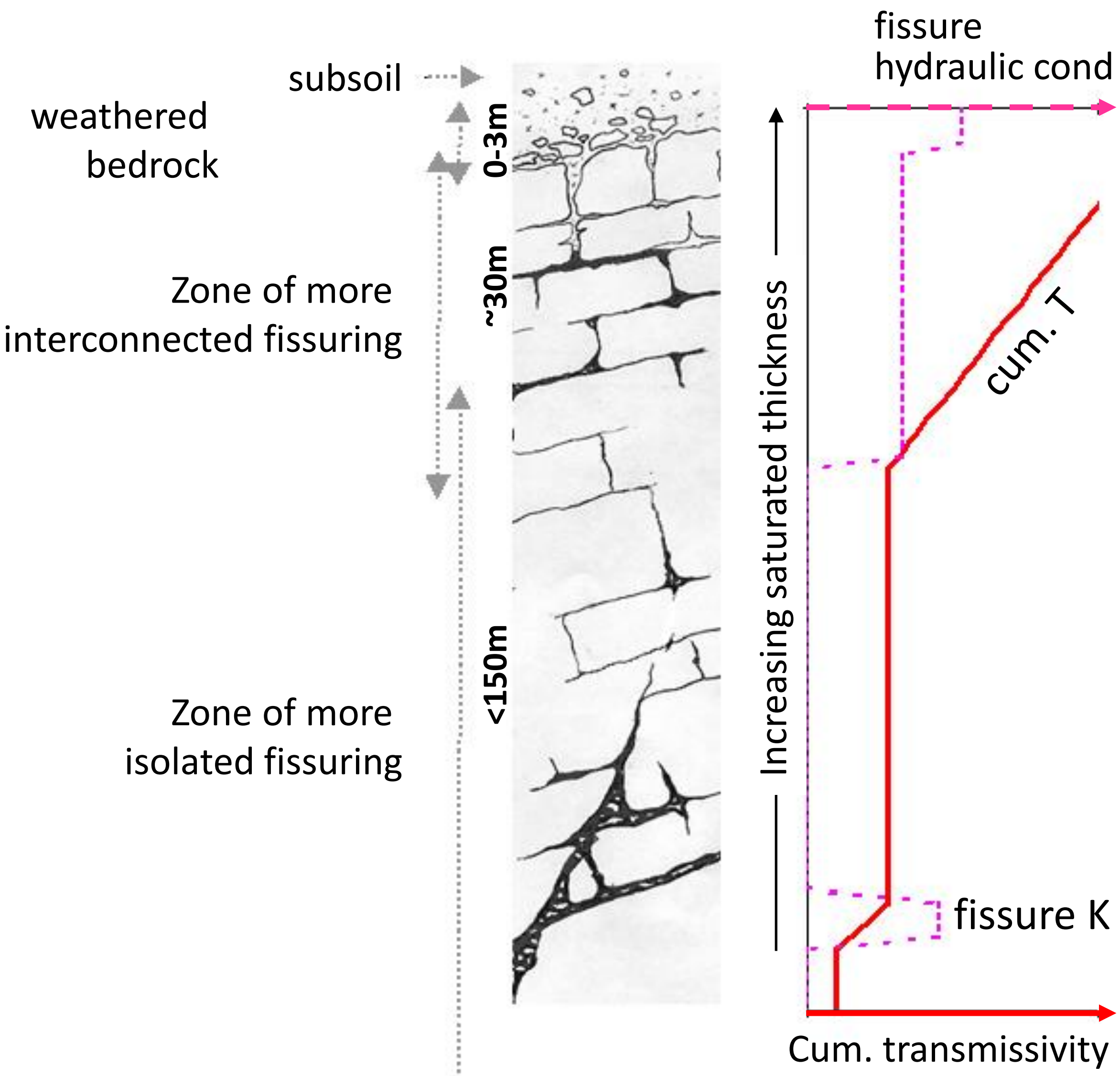
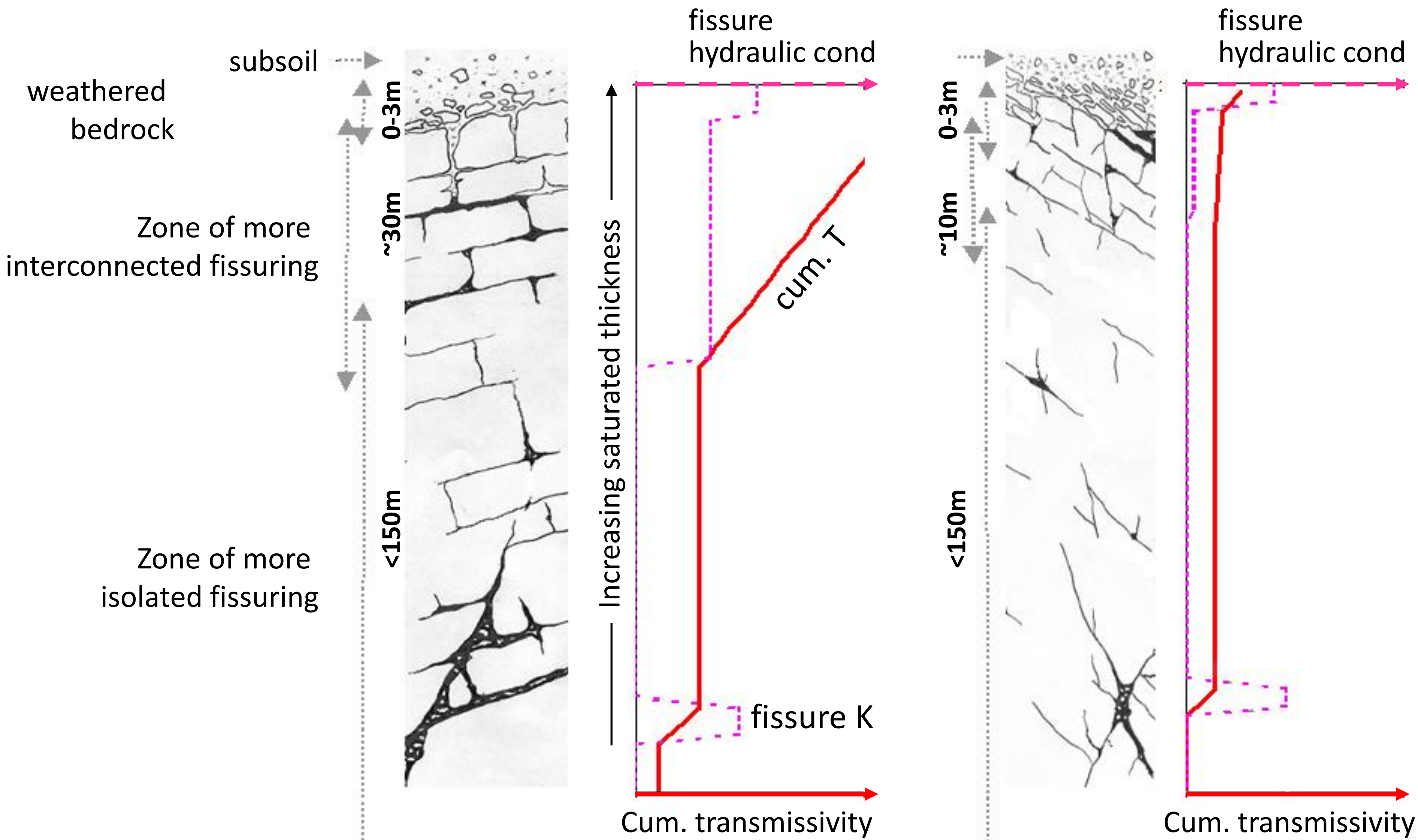

2m
Subsoil
Transition zone
Shallow bedrock
Subsoils/ transition zone
Shallow bedrock
60m
Deep bedrock
fissure issuing water
Dense network of weathered/broken pieces of rock
Frequent connected fractures
Few isolated fractures

Generally transmissive fissured aquifer

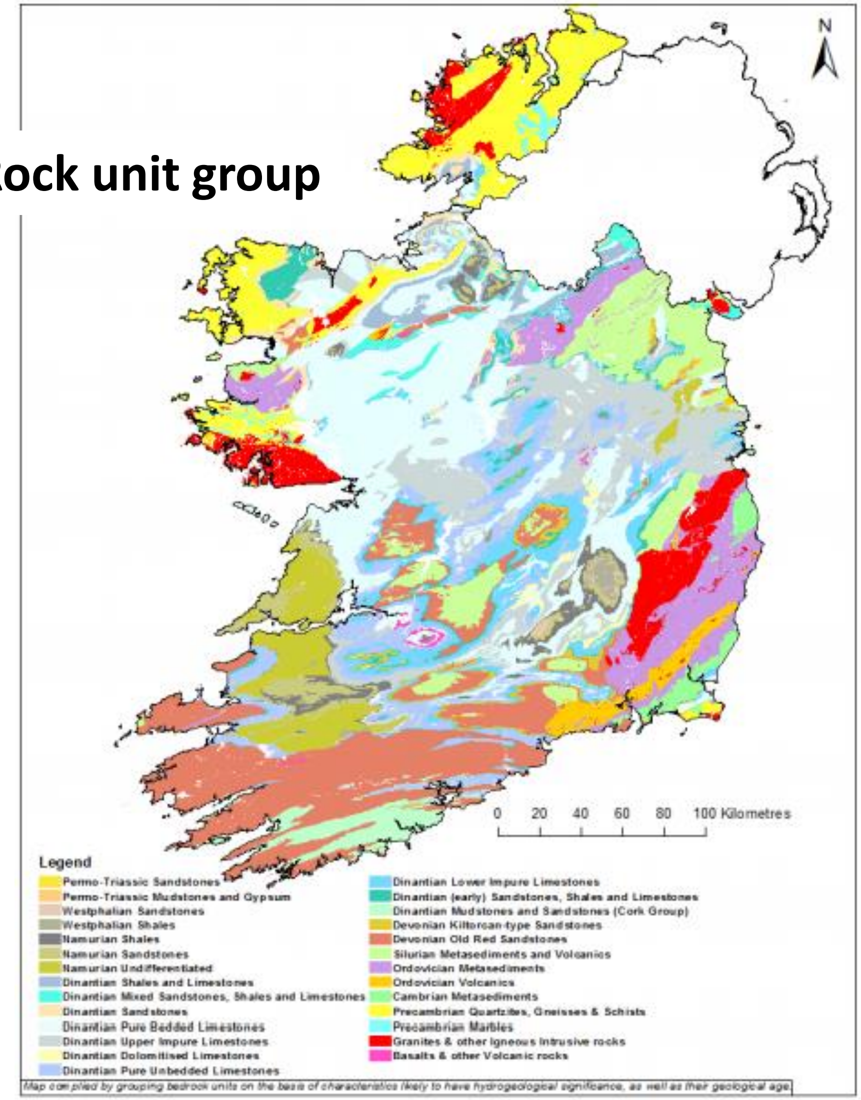


Generally transmissive fissured aquifer

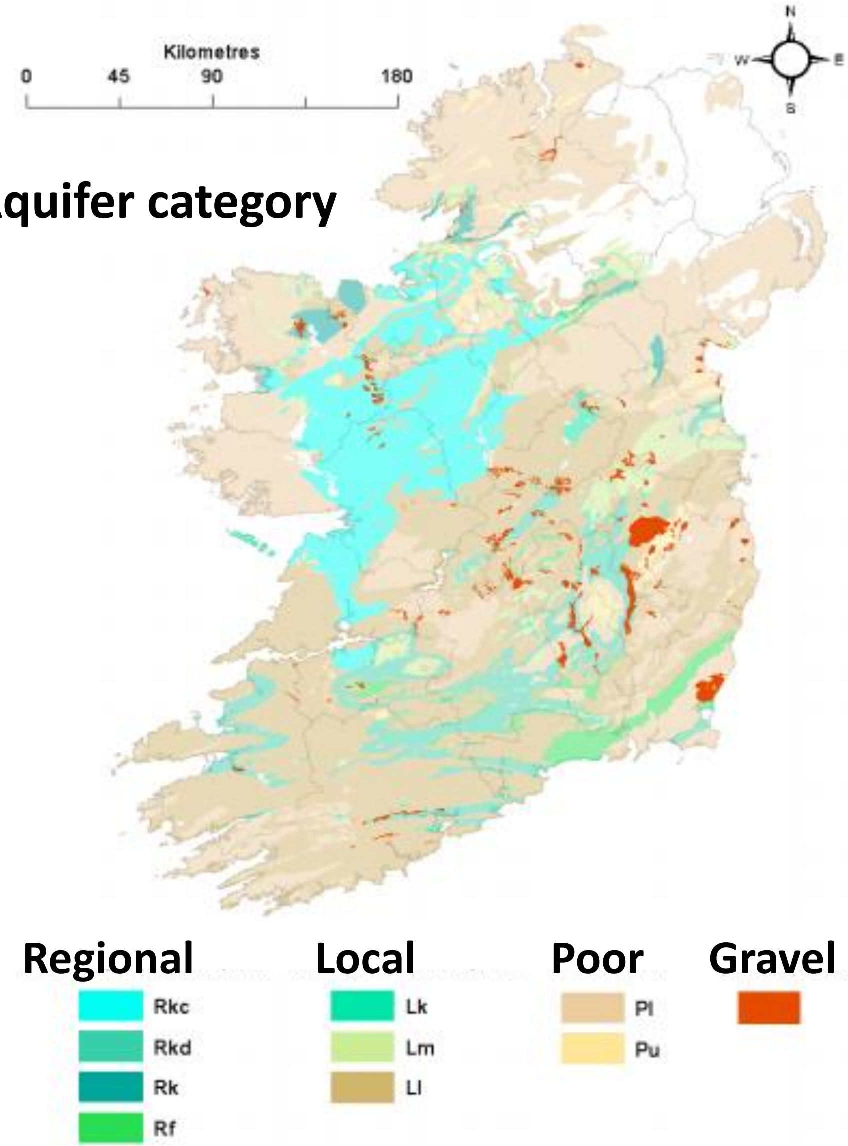
Generally poorly transmissive aquifer



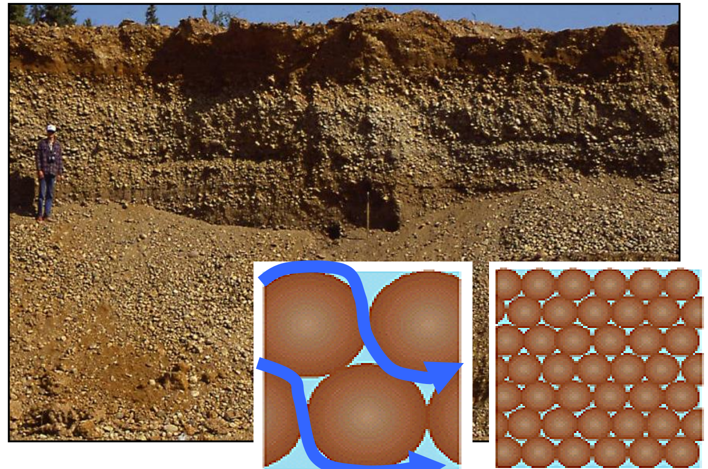
Rock unit group

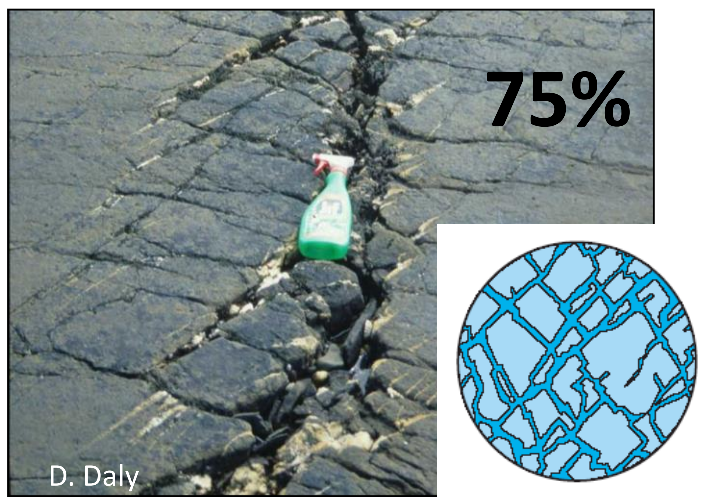


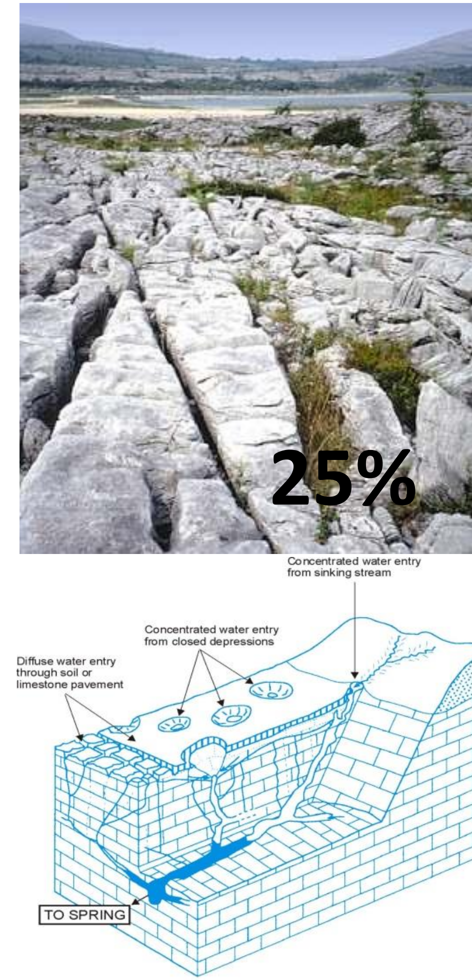
Aquifer category



- Groundwater storage
- Groundwater flow
- Contaminant transport

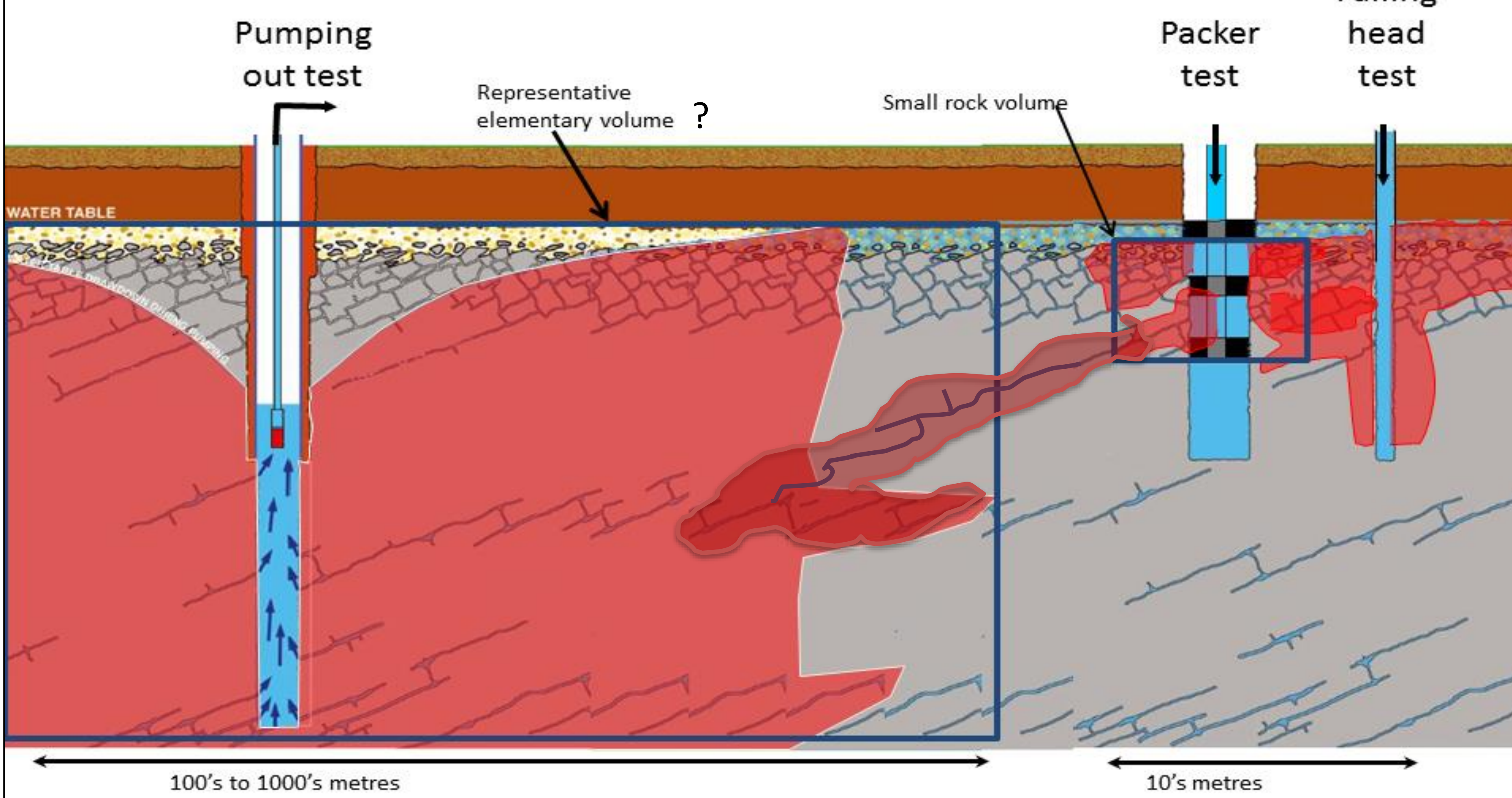




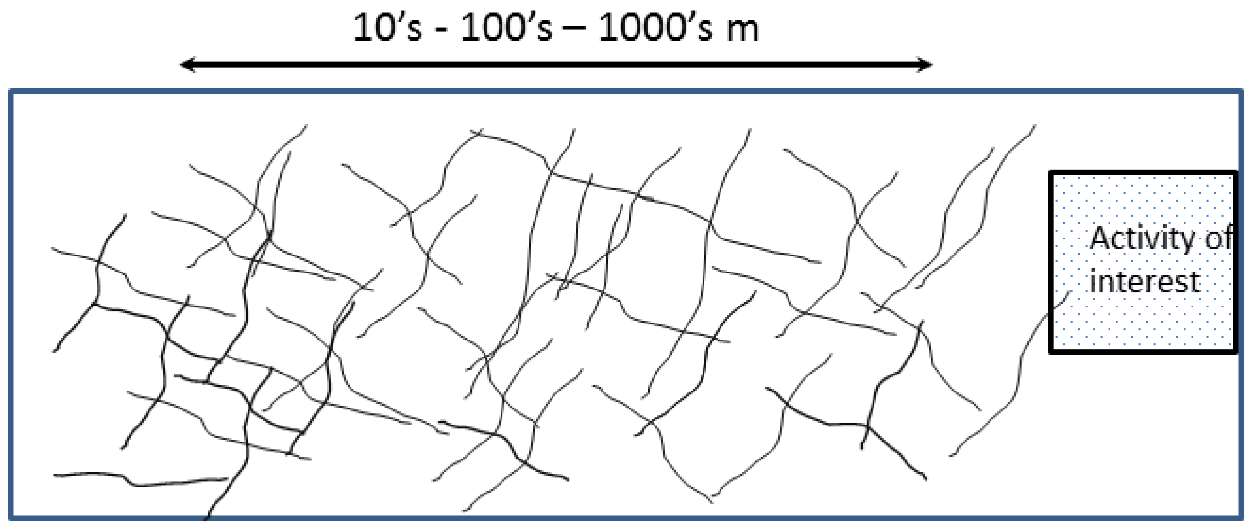


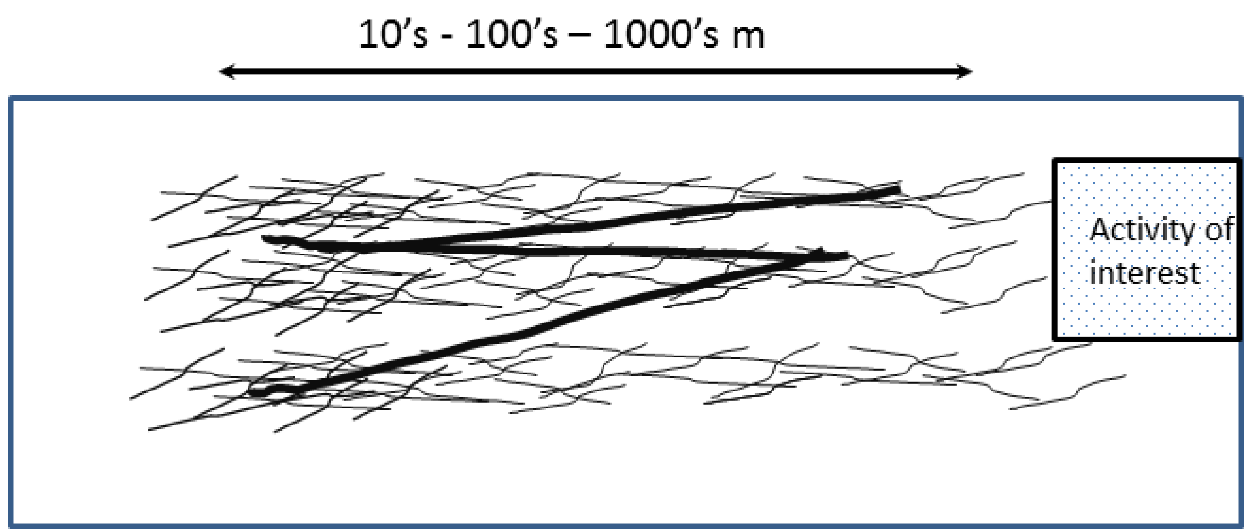
ESTIMATING HYDRAULIC PROPERTIES

Scale of measurement



Anisotropy and scale of heterogeneity
(plan view)





Limitations of typical Irish pumping test data

– <u>analytical assumptions not met</u>
– relatively short tests
– declining or variable pumping rates
– unknown geology/ construction details
– frequently single well
– none/inadequate observation well data
– throttling of different fractures
– bias towards one single large fracture
– often only yield and specific capacity reported

DATABASE

- Scottish Aquifer Properties project & GSI borehole database used as a starting point
- Single row per borehole or test
- Headings arranged in logical groupings
- Fields provide for detailed summary of well & hydraulic testing, allowing best interpretation of results
- Summary tables for Transmissivity
  – by aquifer category and Rock Unit Group

Grouping	Content
RECORD IDENTIFIERS	Name, cross-references, location
BASIC INFORMATION	Depth, DTB, inflows, logs, hydrogeological setting Pathways, RUG, aquifer
CONSTRUCTION DETAILS	borehole construction, screened/open interval, grouting
HYDRAULIC PROPERTIES	Test type, duration, SS/NSS, SC T, K, por, Sy, method, gradient, water levels

Hydraulic Test Type	Test Interval	Test Duration (hours)	Yield (m3/d)	Test Pumping Discharge Rate (m3/d)	Pumping test drawdown (m)	Steady / Non Steady State	Long Term / Current Abstraction rate (m3/d)	Longterm Drawdown (m)

Specific Capacity Range (m3/d/m)	Specific Capacity Pumping Test	Specific Capacity Current abstraction	Specific Capacity_PV	Specific Capacity comment	Productivity Class

Parameter_Estimation_methodolgy	Transmissivity (estimated from SC)	Transmissivity_Preferred (m2/d)	Transmissivity_constant_rate_test (m2/d)	Transmissivity_recovery (m2/d)	Transmissivity_steptest (m2/d)	Transmissivity comment	Transmissivity_Quality

Lugeon	Rock Permeability Range (m/d)	Rock Permeability (m/s)	Rock Permeability mean (m/s)	Rock Permeability mean (m/s)	Rock Permeability mean (m/s)

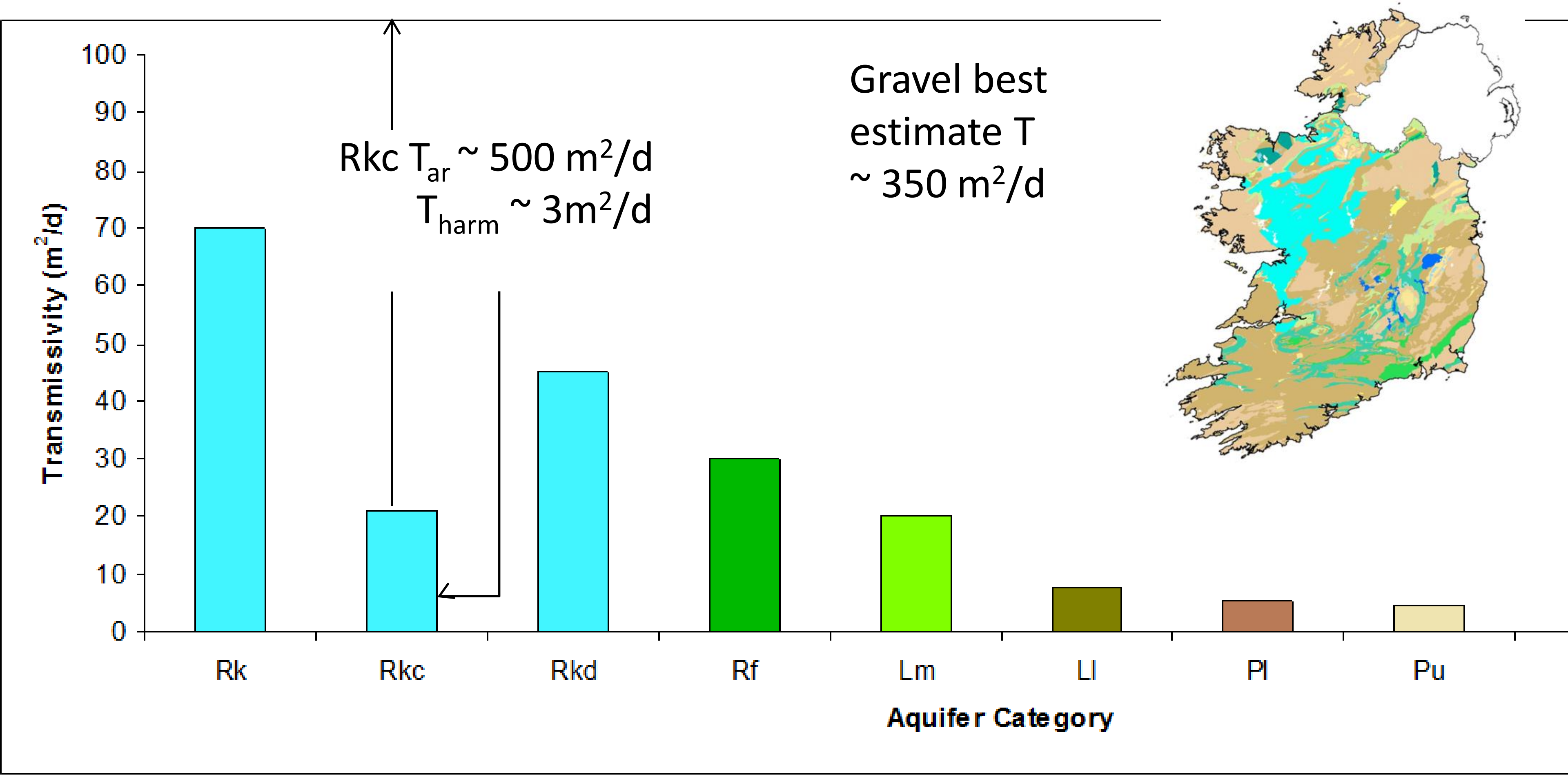
Storativity	Specific Yield	Porosity	Site Gradient	Gradient comment	Static Water level mbgl	Static water level (mAOD)	Pumping Water level (mOD)

- Aquifer parameters database
  - >650 bedrock data, >30 sand & gravel data
  - 55% pumping test data
  - 45% permeability or packer tests, mainly from Dublin or EPA high quality monitoring wells
- GSI Geodata well database
  - > 2,300 specific capacity data (Logan approximation), but not included in the primary database

- Biases in dataset
  - “high” quality T data tend to be from successful water supply investigations
  - “supplementary” data from smaller abstractions with less precise measurements
  - short tests can give overestimates
- Uncertainties in dataset
  - interval(s) being tested
  - influence of heterogeneities
- Number of data per aquifer type similar to area, but rock unit groups over/under-represented

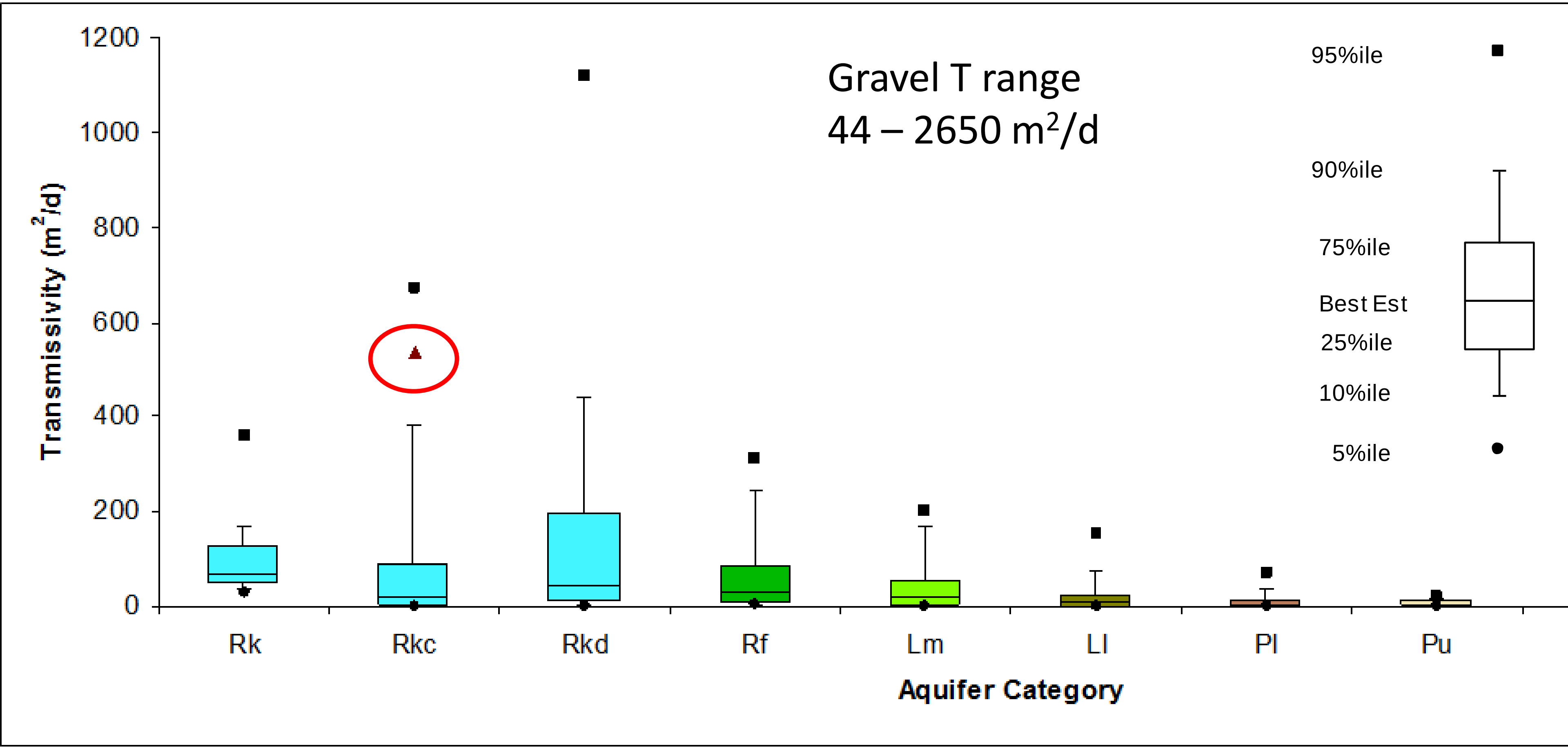
SELECTED SUMMARY DATA

Best estimate T vs aquifer category

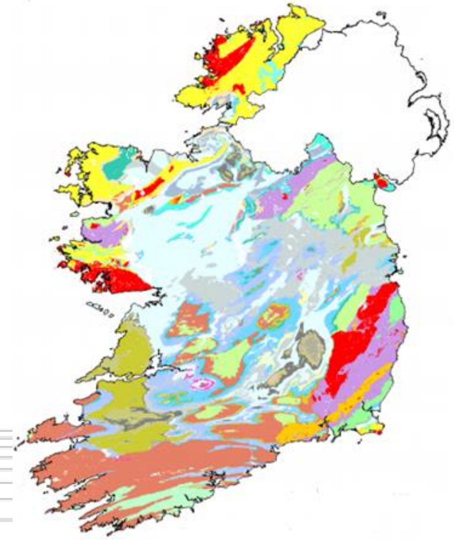


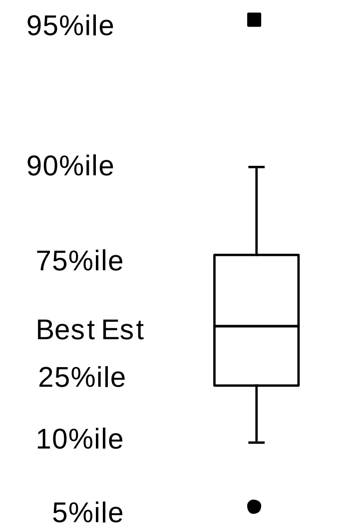
Best estimate: Geometric mean except for Rkc (arithmetic and harmonic)

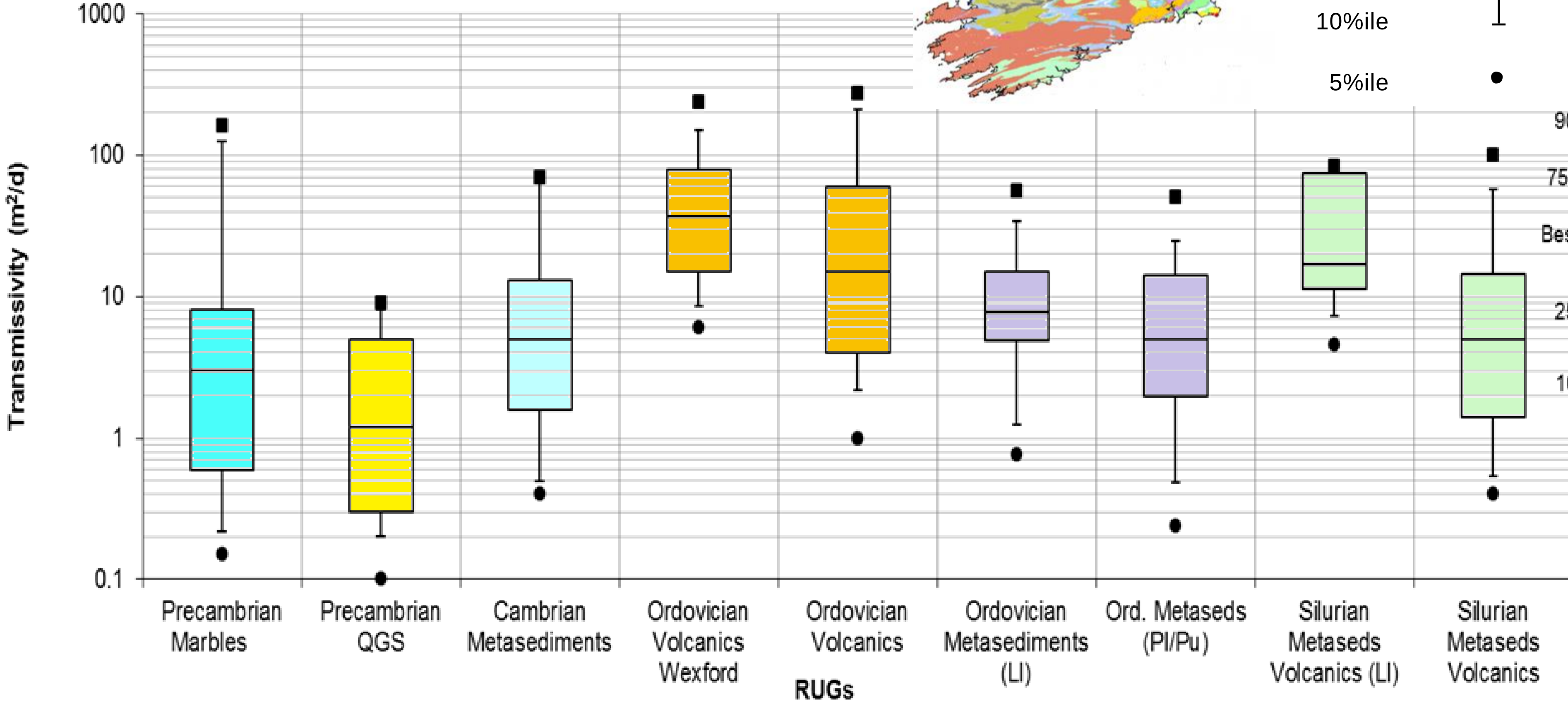
T vs aquifer category



T vs Rock Unit Group







Aquifer category

>>>>> <<

Y

Rock Unit Group

O

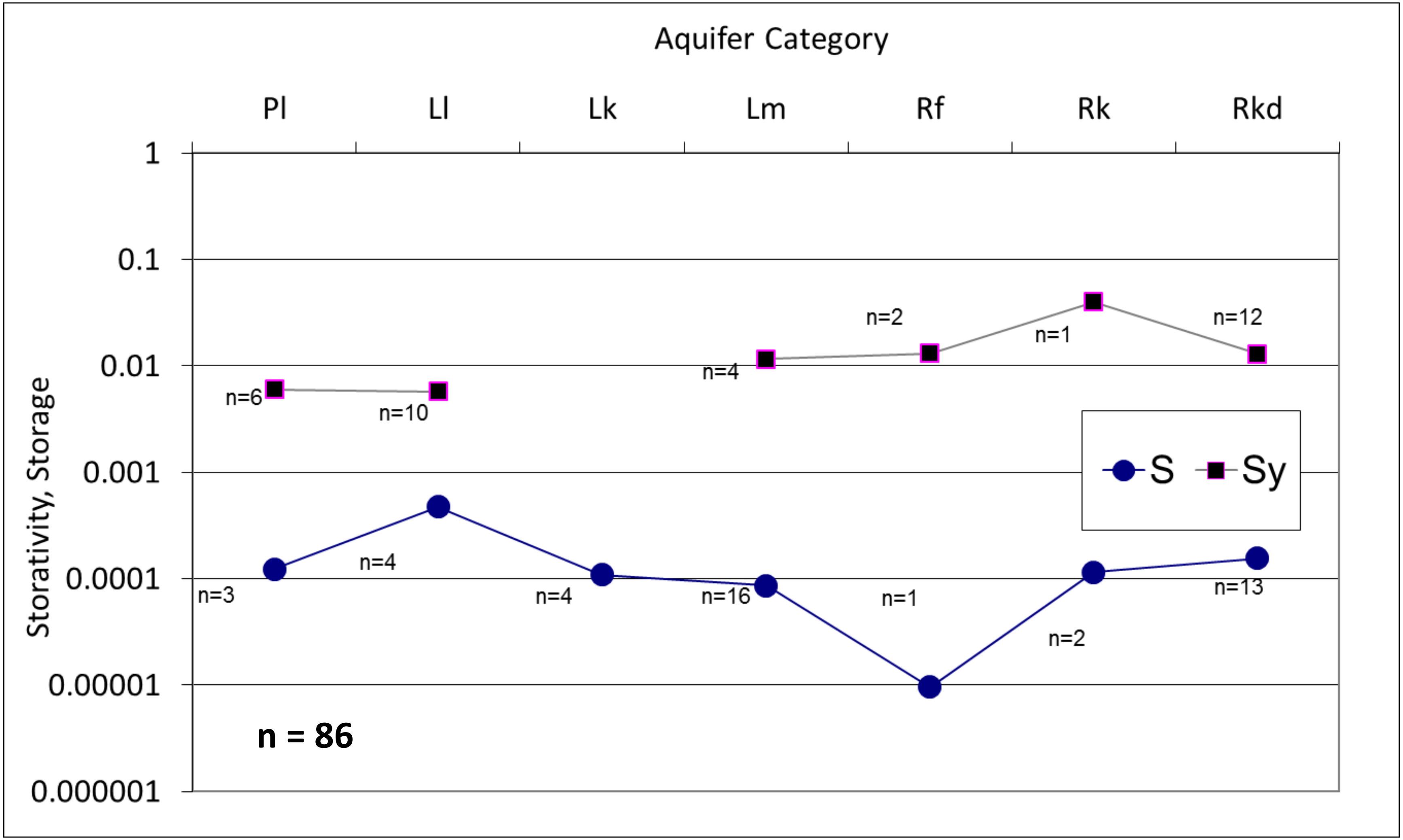
Transmissivity values for Rock Unit Groups per Aquifer Cateogory

Rock Unit	Rk No.	Rk T m2/d Upper Estimates (75, 90, 95 percentile)	Rk T m2/d Lower Estimates (5, 25 percentile)	Rk T m2/d Best Estimate Geomean	Rkc No.	Rkc T m2/d Upper Estimates (75, 90, 95 percentile)	Rkc T m2/d Lower Estimates (5, 25 percentile)	Rkc T m2/d Best Estimate Geomean	Rkd No.	Rkd T m2/d Upper Estimates (75, 90, 95 percentile)	Rkd T m2/d Lower Estimates (5, 25 percentile)	Rkd T m2/d Best Estimate Geomean
	Rk (18)	123 (75%) 174 (90%) 227 (95%)	30 (5%) 48 (25%)	62 (geomean)	Rkc (199)	95 (75%) 400 (90%) 740 (95%)	0.7 (5%) 3.7 (25%)	20 (geomean)	Rkd (190)	196 (75%) 440 (90%) 930 (95%)	1.2 (5%) 10 (25%)	45 (Geomean)
Permo-Triassic sandstones												
Permo-Triassic Mudstones and Gypsum												
Westphalian Sandstones												
Westphalian Shales												
Namurian Shales												
Namurian Sandstones												
Namurian Undifferentiated												
Dinantian Shales and Limestones												
Dinantian Mixed Sandstones, Shales and Limestones												
Dinantian Sandstones												
Dinantian Pure Bedded Limestones	18	125 (75%), 170 (90%), 360 (95%)	30 (5%) 50 (25%)	70	195	100 (75%), 400 (90%), 800 (95%)	0.66 (5%) 4 (25%)	21 (geomean)	142	215 (75%), 440 (90%), 1100 (95%)	1.1 (5%) 14 (25%)	48 (geomean)
Dinantian Upper Impure Limestones												
Dinantian Dolomitised Limestones									32	100 (75%), 400 (90%), 700 (95%) **Lisheen (400-500)**	3 (5%) 25 (25%) **Lisheen 58 (5%), 242 (25%)**	52 (geomean) **Lisheen 260**
Dinantian Pure Unbedded Limestones					47	200 (75%), 630 (90%), 3000 (95%	2 (5%) 11 (25%)	55 (geomean)	47	200 (75%), 630 (90%), 3000 (95%	2 (5%) 11 (25%)	55 (geomean)
Dinantian Lower Impure Limestones												
Dinantian (early) Sandstones, Shales and Limestones												
Dinantian Mudstones and Sandstones (Cork Group)												
Devonian Kiltorcan-type Sandstones												
Devonian Old Red Sandstones												
Silurian Metasediments and Volcanics												
Ordovician Metasediments												
Ordovician Volcanics												
Ordovician Volcanics												
Cambrian Metasediments												
Precambrian Quartzites, Gneisses & Schists												
Precambrian Marbles												
Granites & other Igneous Intrusive rocks												
Basalts & other Volcanic rocks												

Rock Unit	Lk No.	Lk T m2/d Upper Estimates (75, 90, 95 percentile)	Lk T m2/d Lower Estimates (5, 25 percentile)	Lk T m2/d Best Estimate Geomean	Rf No.	Rf T m2/d Upper Estimates (75, 90, 95 percentile)	Rf T m2/d Lower Estimates (5, 25 percentile)	Rf T m2/d Best Estimate Geomean	Lm No.	Lm T m2/d Upper Estimates (75, 90, 95 percentile)	Lm T m2/d Lower Estimates (5, 25 percentile)	Lm T m2/d Best Estimate Geomean
	Lk (25)	66 (75%) 185 (90%) 1440 (95%)	1 (5%) 5 (25%)	20 (geomean)	Rf (160)	85 (75%) 245 (90%) 312 (95%)	3 (5%) 8 (25%)	30 (Geomean)	Lm (132)	50 (75%) 150 (90%) 200 (95%)	1 (5%) 7 (25%)	20 (geomean)
Permo-Triassic sandstones									Lm (132)	50 (75%) 150 (90%) 200 (95%)	1 (5%) 7 (25%)	20 (geomean)
Permo-Triassic Mudstones and Gypsum												
Westphalian Sandstones									19	52 (75%) 110 (90%) 150 (95%)	5 (5%) 8 (25%)	20 (geomean)
Westphalian Shales												
Namurian Shales												
Namurian Sandstones										55 (75%) 180 (90%) 320 (95%)	14 (5%) 30 (25%)	45 (geomean)
Namurian Undifferentiated									Nu (Lm) 8	55 (75%) 180 (90%) 320 (95%)	14 (5%) 30 (25%)	45 (geomean)
Dinantian Shales and Limestones									16	50 (75%), 135 (90%), 160 (95%)	14 (25%)	26 (geomean)
Dinantian Mixed Sandstones, Shales and Limestones									Lm (132)	50 (75%) 150 (90%) 200 (95%)	1 (5%) 7 (25%)	20 (geomean)
Dinantian Sandstones					No data	31 (75%) 40 (90%) 80 (95%)	4 (5%) 12 (25%)	12	9	31 (75%) 40 (90%) 80 (95%)	4 (5%) 12 (25%)	12
Dinantian Pure Bedded Limestones	using Rkc	100 (75%), 400 (90%), 800 (95%)	0.66 (5%) 4 (25%)	21 (geomean)					23	30 (75%), 40 (90%), 190 (95%)	0.8 (5%) 3 (25%)	8 (geomean)
Dinantian Upper Impure Limestones	10	14 (75%), 70 (90%), 80 (95%)	1-2 (5-25%)	6 (geomean)					50	65 (75%), 167 (90%), 200 (95%)	2 (5%) 11 (25%)	25 (geomean)
Dinantian Dolomitised Limestones	32	100 (75%), 400 (90%), 700 (95%)	3 (5%) 25 (25%)	52 (geomean)								
Dinantian Pure Unbedded Limestones	47	200 (75%), 630 (90%), 3000 (95%	2 (5%) 11 (25%)	55 (geomean)								
Dinantian Lower Impure Limestones					12	213 (75%) 600 (90-95%)	7.5 (5%) 20 (25%)	60 (geomean)	No data	213 (75%) 600 (90-95%)	7.5 (5%) 20 (25%)	60 (geomean)
Dinantian (early) Sandstones, Shales and Limestones					12	97 (75%) 151 (90%) 450 (95%)	11 (5%) 23 (25%)	50 (geomean)				
Dinantian Mudstones and Sandstones (Cork Group)												
Devonian Kiltorcan-type Sandstones					39	98 (75%) 316 (90%) 720 (95%)	4 (5%) 11 (25%)	37 (geomean)	39	98 (75%) 316 (90%) 720 (95%)	4 (5%) 11 (25%)	37 (geomean)
Devonian Old Red Sandstones												
Silurian Metasediments and Volcanics												
Ordovician Metasediments					46	60 (75%) 208 (90%) 274 (95%)	3 (5%) 4(25%)	15 (geomean)				
Ordovician Volcanics				wexford	60	79(75%) 151 (90%) 235 (95%)	6 (5%) 15 (25%)	37 (geomean)	60	79(75%) 151 (90%) 235 (95%)	6 (5%) 15 (25%)	37 (geomean)
Ordovician Volcanics				elsewhere	46	60 (75%) 208 (90%) 274 (95%)	1 (5%) 4(25%)	15 (geomean)				
Cambrian Metasediments												
Precambrian Quartzites, Gneisses & Schists												
Precambrian Marbles												
Granites & other Igneous Intrusive rocks												
Basalts & other Volcanic rocks									Lm (132)	50 (75%) 150 (90%) 200 (95%)	1 (5%) 7 (25%)	20 (geomean)

Rock Unit	Ll No.	Ll T m2/d Upper Estimates (75, 90, 95 percentile)	Ll T m2/d Lower Estimates (5, 25 percentile)	Ll T m2/d Best Estimate Geomean	Pl No.	Pl T m2/d Upper Estimates (75, 90, 95 percentile)	Pl T m2/d Lower Estimates (5, 25 percentile)	Pl T m2/d Best Estimate Geomean	Pu No.	Pu T m2/d Upper Estimates (75, 90, 95 percentile)	Pu T m2/d Lower Estimates (5, 25 percentile)	Pu T m2/d Best Estimate Geomean
	Ll (1210)	28 (75%) 98 (90%), 164 (95%)	0.5 (5%) 2 (25%)	8 (geomean)	Pl (392)	18 (75), 90 (90-95%)	0.4 (5%), 1.4 (25%)	5 (geomean)	Pu (26)	12 (75%), 20 (90%), 22 (95%)	1 (5%) 2 (25%)	5.5 (geomean)
Permo-Triassic sandstones												
Permo-Triassic Mudstones and Gypsum					Pl (392)	18 (75), 90 (90-95%)	0.4 (5%), 1.4 (25%)	5 (geomean)				
Westphalian Sandstones												
Westphalian Shales									Pu (26)	12 (75%), 20 (90%), 22 (95%)	1 (5%) 2 (25%)	5.5 (geomean)
Namurian Shales	8	43 (75%), 227 (90%), 400 (95%)	7 (25%)	22 (geomean)	5	9 (75%), 56 (90%), 72 (95%)	4 (25%)	8 (geomean)	Pu (26)	12 (75%), 20 (90%), 22 (95%)	1 (5%), 2 (25%)	5.5 (geomean)
Namurian Sandstones	32	43 (75%), 134 (90%), 465 (95%)	1.5 (5%) 4 (25%)	17 (geomean)	8	12 (75%), 18 (90%), 23 (95%)	3 (25%)	7 (geomean)				
Namurian Undifferentiated	Ll (1210)	28 (75%), 98 (90%), 164 (95%)	0.5 (5%) 2 (25%)	8 (geomean)	Pl (392)	18 (75), 90 (90-95%)	0.4 (5%), 1.4 (25%)	5 (geomean)				
Dinantian Shales and Limestones	9	20 (75%) 35 (90%-95%)	3 (5%) 8 (25%)	12 (geomean)	Pl (392)	18 (75), 90 (90-95%)	0.4 (5%), 1.4 (25%)	5 (geomean)				
Dinantian Mixed Sandstones, Shales and Limestones	8	60 (75%) 70 (90-95%)	2 (5%) 5(25)	16 (geomean)								
Dinantian Sandstones	Ll (1210)	28 (75%) 98 (90%), 164 (95%)	0.5 (5%) 2 (25%)	8 (geomean)								
Dinantian Pure Bedded Limestones												
Dinantian Upper Impure Limestones	98	17 (75%), 54 (90%), 100 (95%)	3 (25%)	8	Pl (392)	18 (75), 90 (90-95%)	0.4 (5%), 1.4 (25%)	5 (geomean)				
Dinantian Dolomitised Limestones												
Dinantian Pure Unbedded Limestones	115	24 (75%), 50 (90%), 70 (95%)	1.2 (25%), 0.3 (5%)	6 (geomean)								
Dinantian Lower Impure Limestones	182	30 (75%), 90 (90%), 200 (95%)	0.36 (5%) 2 (25%)	8 (geomean)								
Dinantian (early) Sandstones, Shales and Limestones	31	36 (75%) 96 (90%) 120 (95%)	0.5 (5%) 6 (25%)	12 (geomean)	15	8 (75%) 11 (90%) 12 (95%)	0.77 (5%) 1.2 (25%)	3 (geomean)				
Dinantian Mudstones and Sandstones (Cork Group)	81	13 (75%) 40 (90%) 65 (95%)	0.6 (5%) 1.8 (25%)	5								
Devonian Kiltorcan-type Sandstones												
Devonian Old Red Sandstones	280	11 (75%) 30 (90%) 75 (95%)	0.65 (5%) 2 (25%)	5 (geomean)	49	3 (75%) 7 (90%) 24 (95%)	0.46 (5%) 0.8 (25%)	2 (geomean)				
Silurian Metasediments and Volcanics	9	65 (75%), 150 (90%), 166 (95%)	5 (5%) 11 (25%)	17 (geomean)	121	14(75%) 57 (90%) 100 (95%)	0.4 (5%) 1.4 (25%)	5 (geomean)	Pu (26)	12 (75%) 20 (90%) 22 (95%)	1 (5%), 2 (25%)	5.5 (geomean)
Ordovician Metasediments	93	15 (75%) 34 (90%) 56 (95%)	1 (5%) 5 (25%)	8 (geomean)	83	14 (75%) 25 (90%) 46 (95%)	0.2 (5%) 2 (25%)	5 (geomean)	83	14 (75%) 25 (90%) 46 (95%)	0.2 (5%) 2 (25%)	5 (geomean)
Ordovician Volcanics	Ll (1210)	28 (75%) 98 (90%), 164 (95%)	0.5 (5%) 2 (25%)	8 (geomean)	Pl (392)	18 (75), 90 (90-95%)	0.4 (5%) 1.4 (25%)	5 (geomean)				
Ordovician Volcanics												
Cambrian Metasediments					27	13 (75%) 70 (90-95%)	0.4 (5%), 1.6 (25%)	5				
Precambrian Quartzites, Gneisses & Schists					62	3.8 (75%) 8.3 (90%) 9 (95%)	0.1 (5%) 0.3 (25%)	1.2 (geomean)	66	9 (95%)	0.3 (25%)	1.2 (geomean)
Precambrian Marbles	16	8 (75%) 160 (95%)	0.6 (25%)	3	16	8	0.6 (25%)	3				
Granites & other Igneous Intrusive rocks	44	31 (75%) 52 (90%) 85 (95%)	1 (5%) 2.4 (25%)	9 (geomean)	44	6 (75%) 13 (90%) 17 (95%)	0.2 (5%) 0.7 (25%)	2				
Basalts & other Volcanic rocks	Ll (1210)	28 (75%) 98 (90%), 164 (95%)	0.5 (5%) 2 (25%)	8 (geomean)								

No.	T m2/d Upper Estimates (75, 90, 95 percentile)	T m2/d Lower Estimates (5, 25 percentile)	T m2/d Best Estimate Geomean
47	200 (75%), 630 (90%), 3000 (95%	2 (5%) 11 (25%)	55 (geomean)



25-29th September 2016
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43rd IAH congress

Summary

- Compiled >600 data, many 3rd party
  - Screening for quality, detailed ‘paper trail’
- Issues with data
  - ‘pseudo T’, ‘bulk K’, fracture K, biases
  - obtaining data – no legal framework
- Database is beginning of a useful reference for practitioners within a hydrostratigraphic framework
- Summary tables indicate typical properties and ranges
- Focus on transmissivity, more fracture K and storage parameters needed


IRISH AQUIFER PROPERTIES –

A REFERENCE MANUAL AND GUIDE

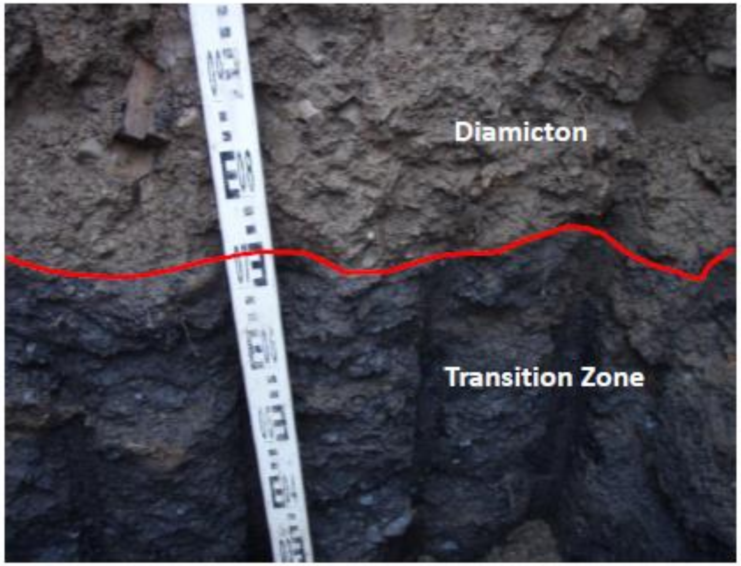
VERSION 1 MARCH 2015

http://www.gsi.ie/programmes/groundwater/aquifer+classification

Transition Zone

The Transition Zone is the broken, weathered zone between the subsoil and competent, unaltered bedrock. It may be formed by **chemical** weathering, or **physical** processes, or both. It is **laterally inhomogeneous** and **may be absent** in places. It may have a different **permeability** to the subsoil and bedrock, and can act as a **significant pathway** for groundwater flow. In some cases, it may also serve to **attenuate** potential contaminants.

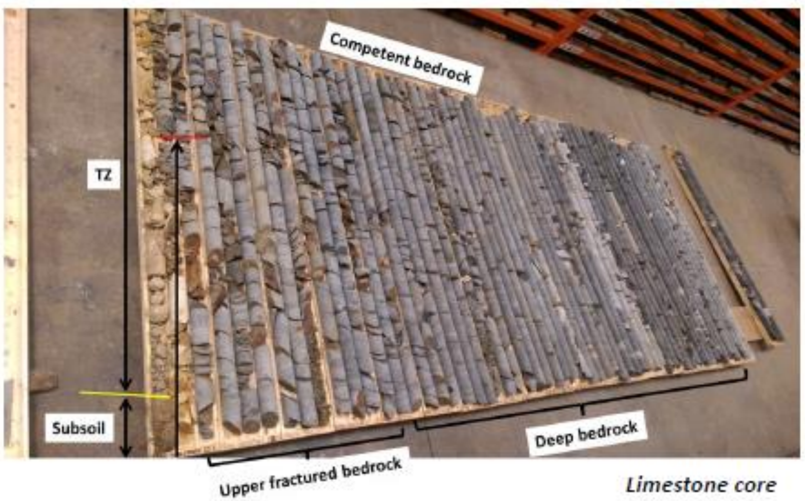
Katie Tedd, GSI
Sarah Blake, GSI/GDG



Cambrian quartzites and mudstones, Co. Dublin

TZ Work Plan

- Outcrop mapping and further population of TZ Story Map
- Systematic logging and classification of TZ sections and bedrock cores
- Link TZ to hydraulic properties (e.g., geophysical surveys, field and laboratory experiments)



Limestone core

Carboniferous limestones, Co. Wexford

The Transition Zone Story Map

http://j.mp/groundwaterstorymap