Groundwater Asset Management

Hydrogeological Group Meeting, Geological Society

10 September 2008

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Turbidity Monitoring

Sand Content Monitoring

Andreas Charalambous, Hydrolaw
Mike Packman, Southern Water
Bertrand Burnet, Scott Wilson

Hydrolaw Consultants Southern Water Scott Wilson

Groundwater Asset Management
Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Based on Borehole Stability

- Unconsolidated: Borehole collapses if unsupported.
  Ex: Alluvial sand and gravels;
  Very friable sandstone.
- Semi-Consolidated: Borehole or part of the borehole collapses soon after drilling (less than a few days).
  Ex: Poorly cemented and/or friable sandstone.
- Consolidated: Borehole stays open without support for long periods (often years).
  Ex: Well cemented sandstone.

Hydrolaw Consultants Southern Water Scott Wilson

Groundwater Asset Management
Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Cementation

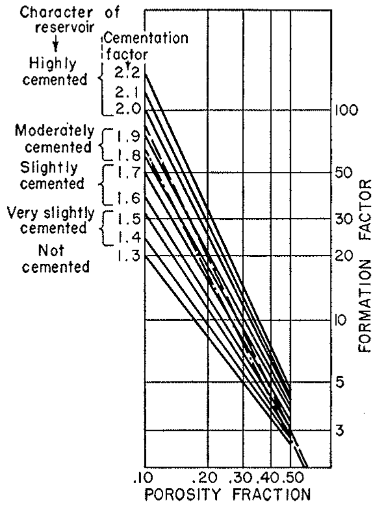
- Formation Factor $F_f = \frac{Rt}{Rw}$

  Rt : aquifer true resistivity (ohm-m)

  Rw : fluid resistivity (ohm-m)

- Knowledge of the formation factor and porosity (P) gives the Cementation Factor (m):

$$F_f = P^{-m}$$



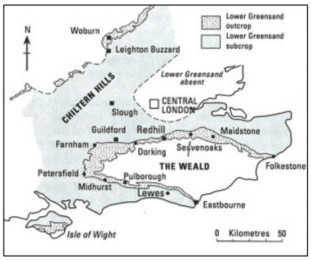
(From Geology of Petroleum, A Levorsen, 2nd edition, 1952)

Hydrolaw Consultants · Southern Water · Scott Wilson

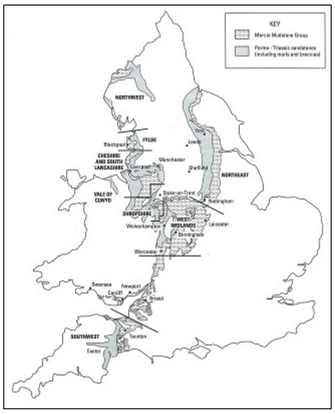
Groundwater Asset Management
Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

UK Aquifers

• Permo-Triassic Sandstone	c. 610 MCM/year
• Lower Greensand	c. 30 MCM/year
• Ashdown Formation	c. 10 MCM/year



Lower Greensand Aquifer



Permo-Triassic Sandstone Aquifer

(From The Physical Properties of Major Aquifer in England & Wales, BGS, 1997)

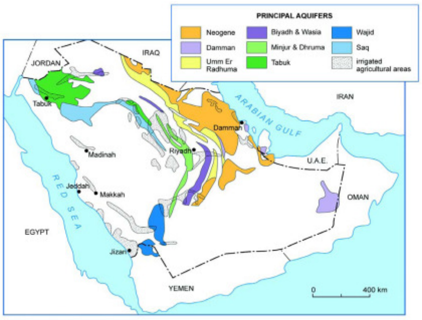
Hydrolaw Consultants · Southern Water · Scott Wilson

Groundwater Asset Management

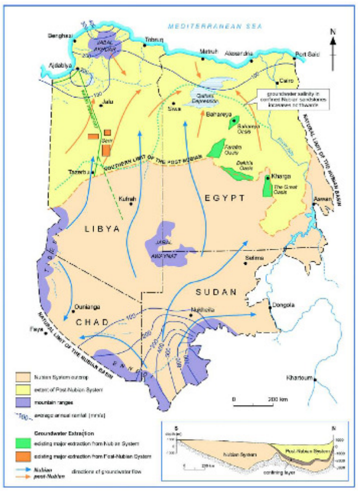
Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Overseas Aquifers

• Disi Saq Sandstone	> 180 MCM/year
• Nubian Sandstone	2,170,000 MCM/year



Principal Aquifers of Saudi Arabia



Nubian Sandstone Aquifer Systems

(From Non-renewable Water Resources, IHP-VI Series on Groundwater No.10, UNESCO)

Hydrolaw Consultants · Southern Water · Scott Wilson

Groundwater Asset Management

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Sand Content and Turbidity Criteria

Sand Content (from US EPA and NWWA, 1975)

Food Processing and Beverages:	1 mg/l
Public Supply / Industry:	5 mg/l
Sprinkler, Cooling:	10 mg/l
Flood, Irrigation:	15 mg/l

Turbidity (Water Supply (Water Quality) Regulations, 2000)

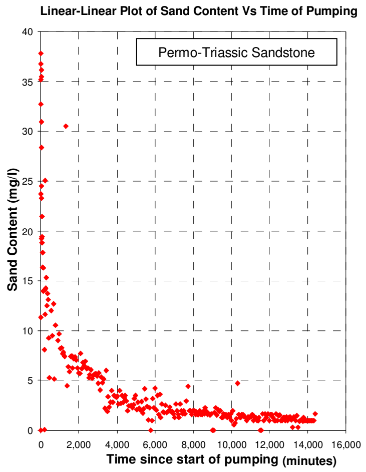
Consumers Tap:	4 NTU
Treatment Works:	1 NTU

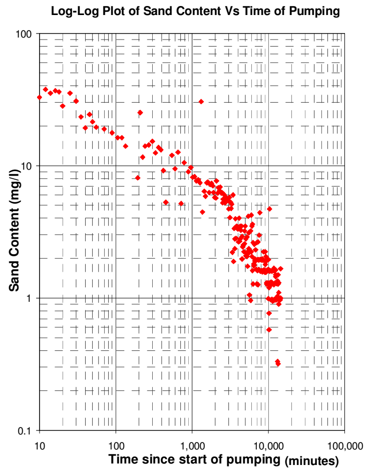
Hydrolaw Consultants · Southern Water · Scott Wilson

Groundwater Asset Management

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Sand Pumping – Relationships: Sand Vs Time





Hydrolaw Consultants · Southern Water · Scott Wilson

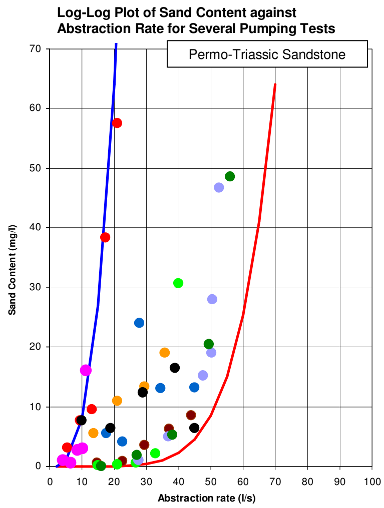
Groundwater Asset Management

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Sand Pumping – Relationships: Sand Vs Abstraction Rate

$C = (Q/K)^n$ (Rossum, 1954)

- C = sand content
- Q = abstraction rate
- K and n are empirical constants



Hydrolaw Consultants · Southern Water · Scott Wilson

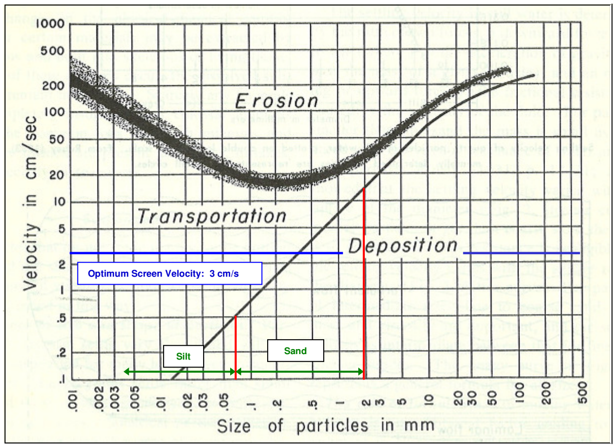
Groundwater Asset Management

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Sediment Movement in Relation to Flow Velocities

Open Channel

	Velocity (cm/s)
Coarse Sand	4 - 15
Medium Sand	1.5 - 4
Fine Sand	0.5 - 1.5
Silt	< 0.5



(From Principles of Stratigraphy, Carl O. Dunbar & John Rodgers, 1957)

Hydrolaw Consultants · Southern Water · Scott Wilson

Groundwater Asset Management

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Well Design

- Unconsolidated Aquifers

  Standard Rules: D_{50} (gravel pack) ≤ 5 – 6 D_{50} (aquifer)
  D_{30} (gravel pack) ≤ 4 – 6 D_{30} (aquifer)

- Semi-Consolidated Aquifers (mostly intergranular flow)

  Above rules would generally be applicable.

  Possibly some loss of yield.

- Consolidated (well cemented, mostly fracture flow)

  Use of gravel pack based on sandstone grain size reduces yield.

  Use of coarse formation stabiliser has less effect on yield; may result in reduction in sand.

  Reduction in sand may be achieved, however, by pumping at lower rate.

Hydrolaw Consultants · Southern Water · Scott Wilson

Groundwater Asset Management

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Well Design

- Multilayered Aquifers (mostly fissure flow)

Use of gravel pack based on finer friable sandstone horizons reduces yield from fractures significantly.

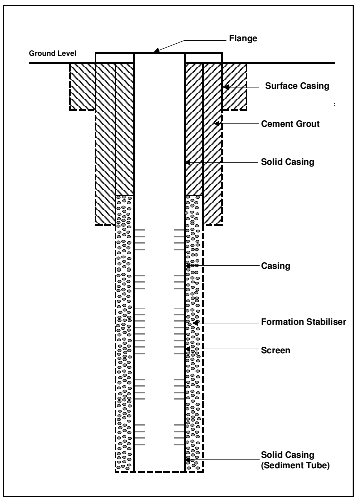
Exclude finer grained horizons using casing; also, coarse grained formation stabiliser and small screen slot width (wirewound screen). Moderate reduction in yield and possibly sand.

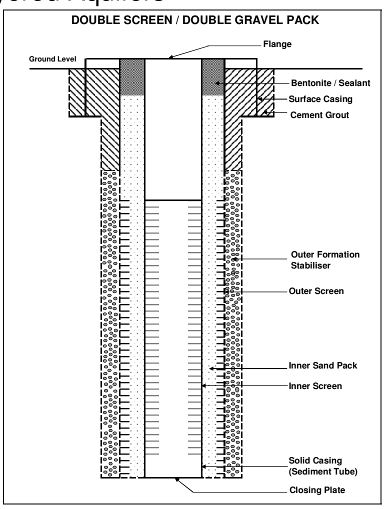
Double pack / double screen outer coarse grained formation stabiliser inner finer pack. To be tried.

Groundwater Asset Management

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Well Design – Multi-layered Aquifers





Groundwater Asset Management

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Impacts of Sand Pumping

- Reduction in Borehole Yield
- Borehole Life
- Pump Life
- Pipeline / Reservoirs
- Economic

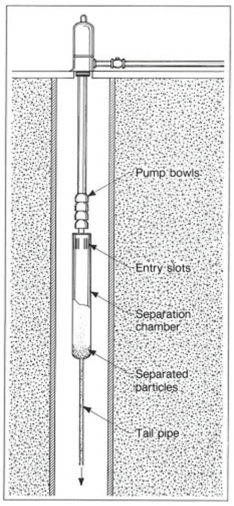
Hydrolaw Consultants | Southern Water | Scott Wilson

Groundwater Asset Management

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Management Options

- Start-up Control (variable speed drive)
- Sand Traps
- Multiple Boreholes



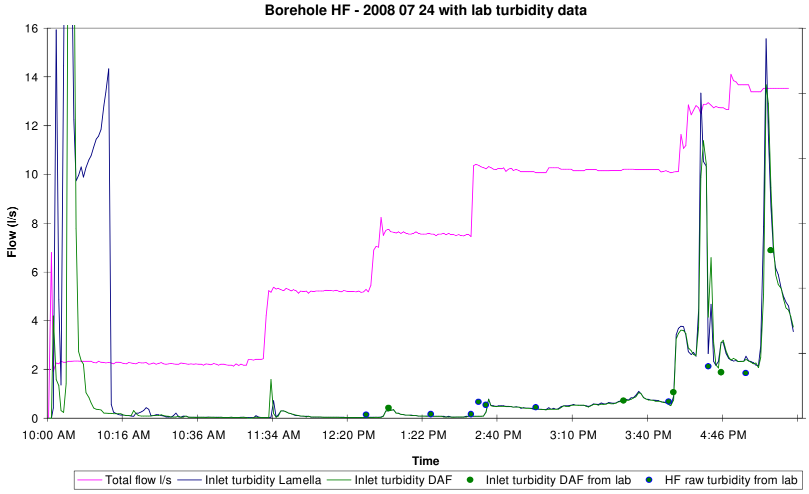
Sand Separator (from Johnson, 2nd Edition)

Hydrolaw Consultants | Southern Water | Scott Wilson

Groundwater Asset Management

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

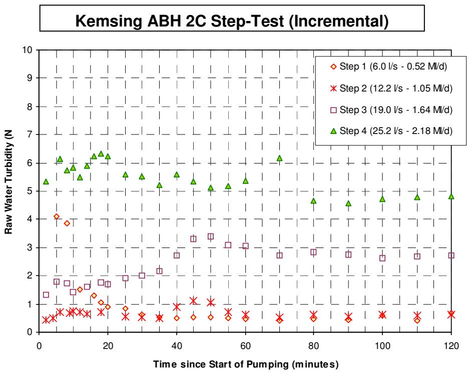
SEW Kemsing Groundwater Source

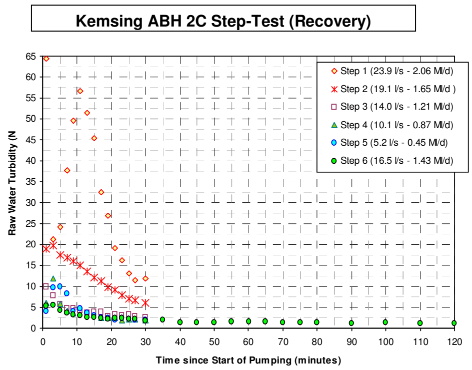


Groundwater Asset Management

Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

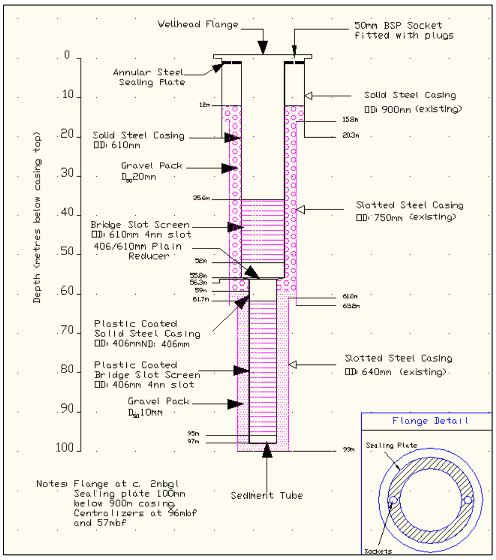
SEW Kemsing Groudwater Source





Groundwater Asset Management
Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

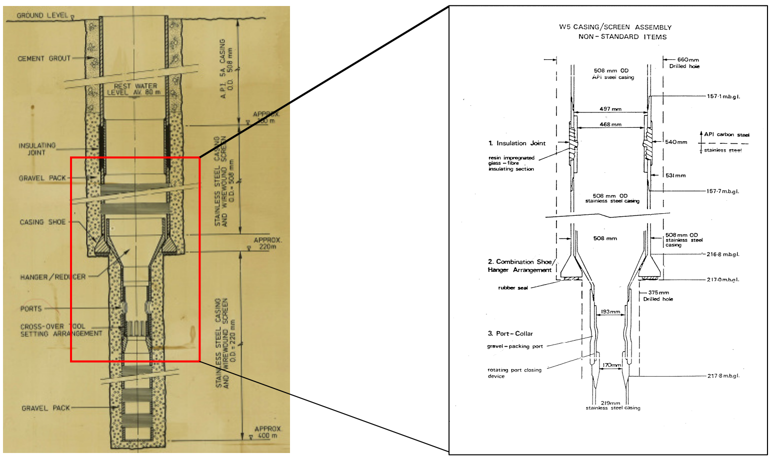
STW Borehole



Hydrolaw Consultants | Southern Water | Scott Wilson

Groundwater Asset Management
Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Typical Design of Production Borehole at Qa Disi



Hydrolaw Consultants | Southern Water | Scott Wilson

Conclusion

- Difficult Problem
- Design Considerations Important
- Learning from Experience
- Research Needed to Evaluate Impacts

Groundwater Asset Management
Well Design and Sand Pumping in Consolidated and Semi-Consolidated Sandstone Aquifers

Acknowledgements

Anglian Water
Environment Agency
Severn Trent Water
South East Water
Southern Water
South Staffordshire Water
Southwest Water
Sutton & East Surrey Water
Thames Water

Thank you