Delaware Geological Survey
Open File Report 45
McKenna, T. E., McLaughlin, P. P., and Benson, R. N., 2004, Characterization of the Potomac Aquifer, an extremely heterogeneous fluvial system in the Atlantic Coastal Plain of Delaware: Delaware Geological Survey Open File Report 45.

SUMMARY

Open File Report 45 is a three panel poster presented at the Society for Sedimentary Geology (SEPM) Research Conference on Ancient and Modern Coastal Plain Depositional Environments: Aquifer Heterogeneity and Environmental Implications, March 24th - 27th, 2002 in Charleston, SC. The abstract is included below for convenience and is also included on Sheet 1 of the oversized sheets.

DISTRIBUTION

Open File Report 45 is a compilation of this summary file with 3 oversized sheets (posters) compiled into a single document in Adobe Portable Document Format (pdf). The report is available for downloading from the Delaware Geological Survey's website (www.udel.edu/dgs under "Publications"). Printed copies are available upon request.

ABSTRACT

Fluvial sands of the subsurface Cretaceous Potomac Formation form a major aquifer system used by a growing population in the northern Coastal Plain of Delaware. The aquifer is extremely heterogeneous on the megascopic scale and connectivity of permeable fluvial units is poorly constrained. The formation is characterized by alluvial plain facies in the updip section where it contains potable water. While over 50 aquifer tests indicate high permeability ($5x10^{-5}$ to $7x10^{-4}$ m/s), the formation is primarily composed of fine-grained silt and clay in overbank and interfluvial facies. Individual fluvial sand bodies are laterally discontinuous and larger-scale sand packages appear to be variable in areal extent resulting in a labyrinth style of heterogeneity. The subsurface distribution of aquifers and aquitards has been interpreted within a new stratigraphic framework based on geophysical logs and on palynological criteria from four cored wells. The strata dip gently to the southeast, with generally sandy fluvial facies at the base of the formation lapping onto a south-dipping basement unconformity. The top of the formation is marked by an erosional unconformity that truncates successively older Potomac strata updip. Younger Cretaceous units overly the formation in its downdip area. In the updip area, the formation crops out or subcrops under Quaternary sands. The fine-grained facies include abundant paleosols that contain siderite nodules and striking mottling that commonly follows ped faces and root traces. These paleosols may serve as regional aquitards. This geologic complexity poses a challenge for determining the magnitudes and directions of ground-water flow within the aquifer that are needed for making informed decisions when managing this resource for water supply and contaminant remediation.

DELAWARE GEOLOGICAL SURVEY
UNIVERSITY OF DELAWARE, NEWARK
John H. Talley, State Geologist

DELAWARE GEOLOGICAL SURVEY
OPEN FILE REPORT NO. 45
SHEET 1

Characterization of the Potomac Aquifer, an extremely heterogeneous fluvial system in the Atlantic Coastal Plain of Delaware

Thomas E. McKenna, Peter P. McLaughlin, and Richard N. Benson

Abstract

Fluvial sands of the subsurface Cretaceous Potomac Formation form a major aquifer system used by a growing population in the northern Coastal Plain of Delaware. The aquifer is extremely heterogeneous on the megascopic scale and connectivity of permeable fluvial units is poorly constrained. The formation is characterized by alluvial plain facies in the updip section where it contains potable water. While over 50 aquifer tests indicate high permeability (5x10-5 to 7x10-4 m/s), the formation is primarily composed of fine-grained silt and clay in overbank and interfluvial facies. Individual fluvial sand bodies are laterally discontinuous and larger-scale sand packages appear to be variable in areal extent resulting in a labyrinth style of heterogeneity. The subsurface distribution of aquifers and aquitards has been interpreted within a new stratigraphic framework based on geophysical logs and on palynological criteria from four cored wells. The strata dip gently to the southeast, with generally sandy fluvial facies at the base of the formation lapping onto a south-dipping basement unconformity. The top of the formation is marked by an erosional unconformity that truncates successively older Potomac strata updip. Younger Cretaceous units overly the formation in it's downdip area. In the updip area, the formation crops out or subcrops Quaternary sands. The fine-grained facies include abundant paleosols that contain siderite nodules and striking mottling that commonly follows ped faces and root traces. These paleosols may serve as regional aquitards. This geologic complexity poses a challenge for determining the magnitudes and directions of ground-water flow within the aquifer that are needed for making informed decisions when managing this resource for water supply and contaminant remediation.

Introduction / Main Issues

- Aquifers in the Potomac Formation are the primary ground-water reservoirs in northern Delaware
- High population growth and increasing water demand make aquifer management critical
- Heterogeneous nature of aquifers complicate determination of magnitudes and directions of ground-water flow

Objectives

- Establish accurate stratigraphic framework as basis for characterizing depositional and aquifer architecture
- Calibrate facies type to geophysical log character using core data
- Estimate distribution of facies types within the updated stratigraphic framework
- Assess aquifer characteristics (permeability, storage properties) and interconnectivity of facies types based on available aquifer test results

Geological Background

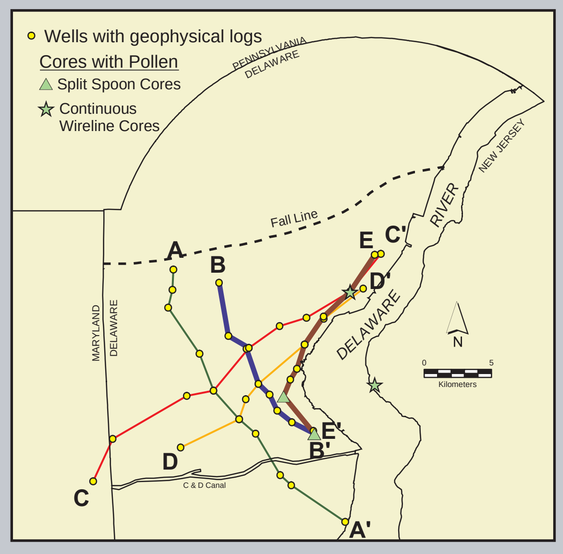
- The Potomac Formation is the lowermost Cretaceous stratigraphic unit in area
- It overlies basement and is capped by a major unconformity
- The aquifers are developed in non-marine facies that include fluvial and overbank deposits with extensive paleosol development

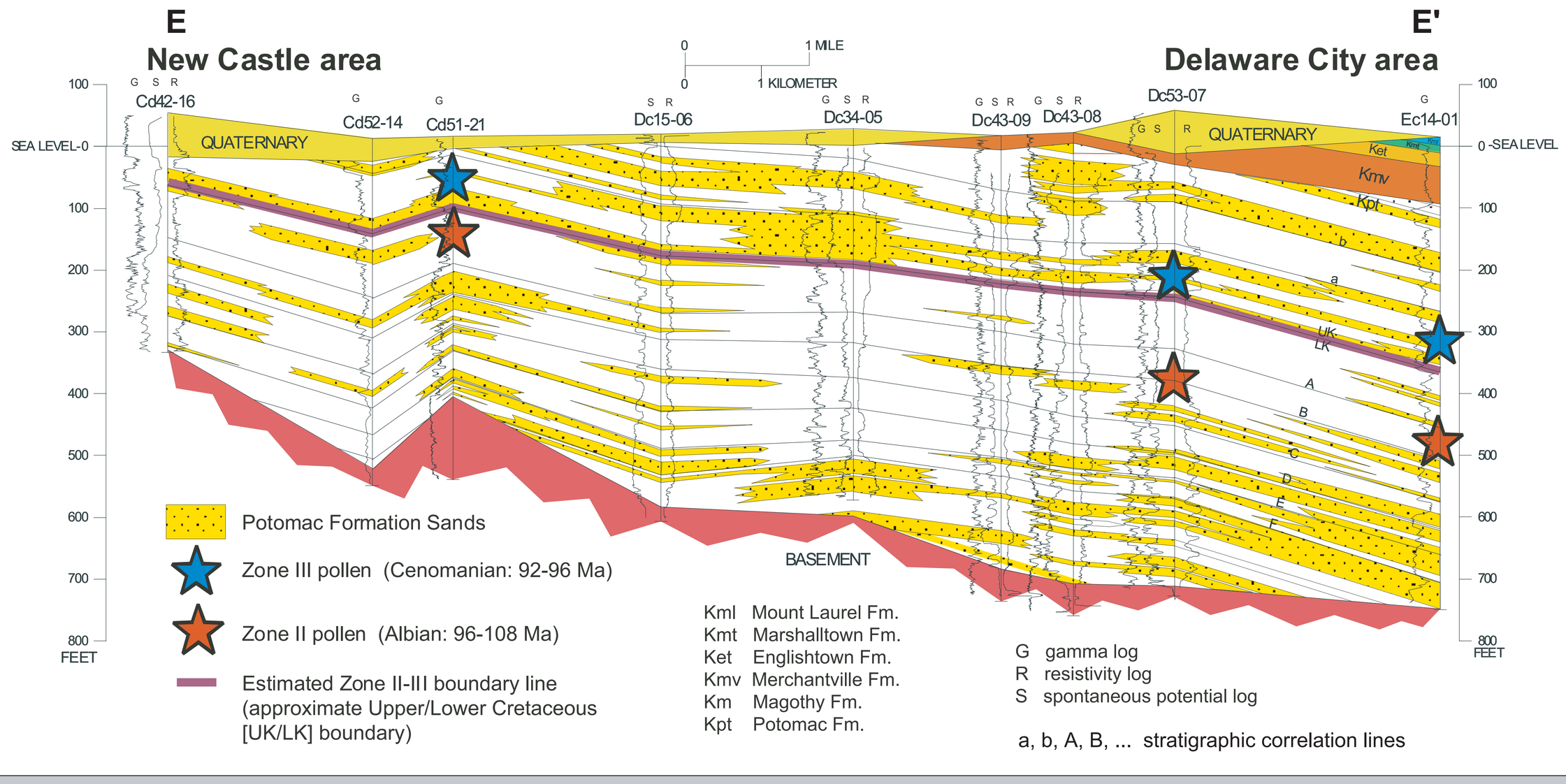
Database

- Detailed sedimentologic analysis on 3 continuously cored holes
- Geophysical and lithologic logs for more than 50 wells
- Palynology in 5 coreholes (3 continuously cored, 2 split-spoon)
- 250 aquifer test analyses (70 with full suite of data)

Stratigraphic Framework

- Potomac Formation overlies a basement composed of crystalline rock or saprolite with significant paleotopographic relief
- Three pollen zones and several subzones constrain stratigraphic correlations
- Top of the formation is marked by a significant (10 m.y.) erosional unconformity with some erosional relief
- The Potomac Formation crops out and subcrops under Quaternary surficial sediments just south of the Fall Line
- Recently updated stratigraphic framework indicates Potomac onlaps basement and is increasingly truncated updip by younger formations - previous aquifer model for area (Martin, 1984) assumed basement-parallel stratigraphy
- Sand correlation is complicated by laterally discontinuous nature of the fluvial facies





References

Bethke, C. M., Lee, M. K., Quinodoz, H. A. M., and Kreiling, W. N., 1993, Basin modeling with Basin2, A guide to using Basin2: Urbana-Champaign, University of Illinois, 225 p.
Dickinson, G., 1953, Geological aspects of abnormal reservoir pressure in Gulf Coast Louisiana: AAPG Bulletin, v. 37, p. 410-432.
Fogg, G. E.,1989, Stochastic Analysis of Aquifer Interconnectedness: Wilcox Group, Trawick Area, East Texas: Univ. TX Bureau of Economic Geology, Report of Investigations 189, 68 p.
Galloway, W. E. and Hobday, D. K., 1996, Terrigenous clastic depositional systems: New York, Springer-Verlag, 2nd ed., 489 p.
Jordan, R. R., 1983, Stratigraphic nomenclature of nonmarine Cretaceous rocks of inner margin of Coastal Plain in Delaware and adjacent states: Delaware Geological Survey Report of Investigations No. 37, 43 p.
Martin, M. M., 1984, Simulated ground-water flow in the Potomac Aquifers, New Castle County, Delaware: USGS Water Resources Investigations Report 84-4007, 85 p.
Reading, H. G., 1986, Sedimentary Environments and Facies: Oxford, Blackwell Scientific Publications, 2nd ed., 615 p.
Retallack, G. J., 1990, Soils of the Past: Boston, Unwin Hyman, 520 p.

DELAWARE GEOLOGICAL SURVEY
UNIVERSITY OF DELAWARE, NEWARK
John H. Talley, State Geologist

Potomac Sedimentology

DELAWARE GEOLOGICAL SURVEY
OPEN FILE REPORT NO. 45
SHEET 2

Facies (Environmental Interpretation)	Sedimentological Characteristics	Core Photo	Core Log	Geophysical Log Character
Amalgamated Sands (Amalgamated Channels)	▶ sand intervals 30-70 ft thick ▶ sharp base, top abrupt, fines at top usually thin or not preserved ▶ mostly fine to medium sand, with less common coarse and very coarse sand ▶ fining-upward packages within these sands commonly 3-10 ft thick ▶ sedimentary structures uncommon, include planar parallel and cross-bedding ▶ blocky log patterns	DGSID: Cd51-21	80 85 90 95 100 105 110 *depths in feet*	GAM(NAT) SP FEET RES(16N) 70 80 90 100 110 120 Example 0 API-GR 180 -120 MV -30 5 OHM-M 500
Thick Sands (Isolated Channels)	▶ individual sands 5-20 ft thick ▶ occur within 10-30-ft-thick fining-upward packages ▶ sands fine upward from fine to medium (less commonly coarse to very coarse) sand to silty very fine sand, fines above are preserved ▶ sedimentary structures uncommon, most commonly cross-bedding ▶ mud chips and scattered charcoal may occur ▶ bell-shaped log patterns	DGSID: Cd51-21	280 285 290 295 300 Example	GAM(NAT) SP FEET RES(16N) 280 290 300 0 API-GR 180 -120 MV -30 5 OHM-M 500
Thin Sands (Crevasse Splay/ Proximal Levee)	▶ sand intervals <10 ft thick, usually 1-3 ft ▶ grain sizes range from coarse to very fine, fining-upward ▶ current ripples evident in places ▶ mud clasts and charcoal are common ▶ irregular log pattern	DGSID: Cd51-21	205 210 215 220 225 Example	GAM(NAT) SP FEET RES(16N) 200 210 220 230 0 API-GR 180 -120 MV -30 5 OHM-M 500
Interlaminated Sand and Silt (Distal Levee/ Flood Plain)	▶ centimeter-scale beds and thinner laminae ▶ includes sandy silt, silty sand, and silty clay, fines predominate ▶ current ripples evident in some thin sand beds ▶ often associated with abundant charcoal, mud clasts in places ▶ irregular log pattern	DGSID: Cd51-23	150 155 160 165 170 Example	GAM(NAT) SP FEET RES(16N) 150 160 170 0 API-GR 180 -10 MV 60 3 OHM-M 300
Mottled Silts & Clays (Weathered Flood Plain with Paleosols)	▶ predominantly variegated silts and clays, light gray, olive-tan, red, orange, purple, or whitish gray ▶ sandy lithologies commonly contain a significant component of silt or clay ▶ exhibits extensive mottling or irregular banding ▶ contains sphaerosiderite in places ▶ irregular log pattern, reduced gamma in paleosols	DGSID: Cd51-23	320 325 330 335 340 Example	GAM(NAT) SP FEET RES(16N) 320 330 340 0 API-GR 180 -10 MV 60 3 OHM-M 300

Core Log Legend: clay; silt; very fine to fine sand; fine to medium sand; coarse to very coarse sand; hematite cement; mottling; mud clast; charcoal

Aquifer / Aquitard Characteristics of Potomac Facies

Amalgamated Sands (Amalgamated Channels)

- Deposition across broad (~ 5 km / 3 mi wide) fluvial valleys yields high lateral continuity
- Clean fine and medium sands have good porosity and permeability
- Few aquitards within sand intervals due to amalgamation of channel sands

Thick Sands (Isolated Channels)

- Deposition in isolated channels yields poor lateral continuity
- Clean fine and medium sands have good porosity and permeability
- Commonly fine upward into silts and clays which may form aquitards

Thin Sands (Crevasse Splay / Proximal Levee)

- Near-channel flood-plain deposition by overbank events yields local sand bodies with poor lateral continuity
- Variable sand permeability, with thin, permeable sand making local aquifers
- Silts and clays within and enclosing this facies are aquitards across parts of the study area

Interlaminated Sand and Silt (Distal Levee / Flood Plain)

- Sands may have broad lateral extent on flood plain, but thin-bedded character makes continuity difficult to establish
- Most sands are silty and less permeable, not aquifer quality
- Silts and clays within and enclosing this facies are aquitards across parts of the study area

Mottled Silts & Clays (Weathered Flood Plain with Paleosols)

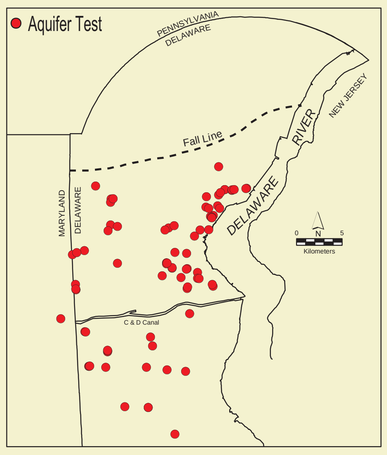
- Important aquitards across study area (and perhaps regionally)
- Dense clays and hard paleosols are not fractured and have very low permeability
- Interbedded thin sands and silts may allow some leakage across aquitards

DELAWARE GEOLOGICAL SURVEY
UNIVERSITY OF DELAWARE, NEWARK
John H. Talley, State Geologist

DELAWARE GEOLOGICAL SURVEY
OPEN FILE REPORT NO. 45
SHEET 3

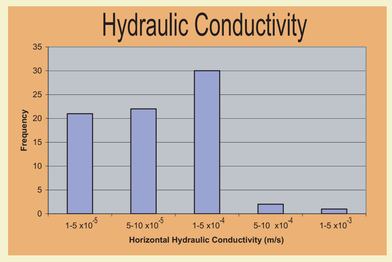
Hydraulic Characteristics

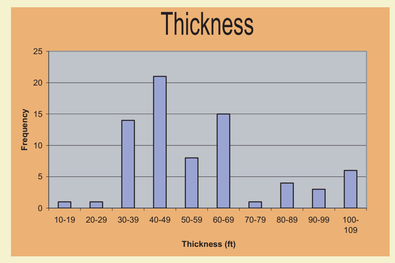
Locations of Aquifer Tests



Aquifers

Stacked Amalgamated and Isolated Channels

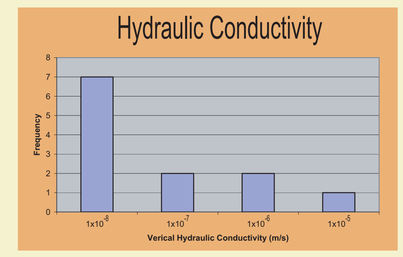




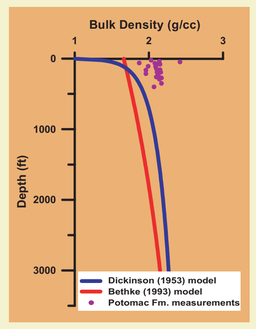
Horizontal Hydraulic Conductivity = 10^{-5} - 10^{-3} m/s (3 - 300 ft/day)
Transmissivity = 4 - 1900 m^2/day (40 - 20,000 ft^2/day)
Storativity = 10^{-4} - 10^{-5}
Thickness = 3 - 30 m (10 - 100 ft)

Aquitards

Distal Levee / Flood Plain, Weathered Flood Plain with Paleosols

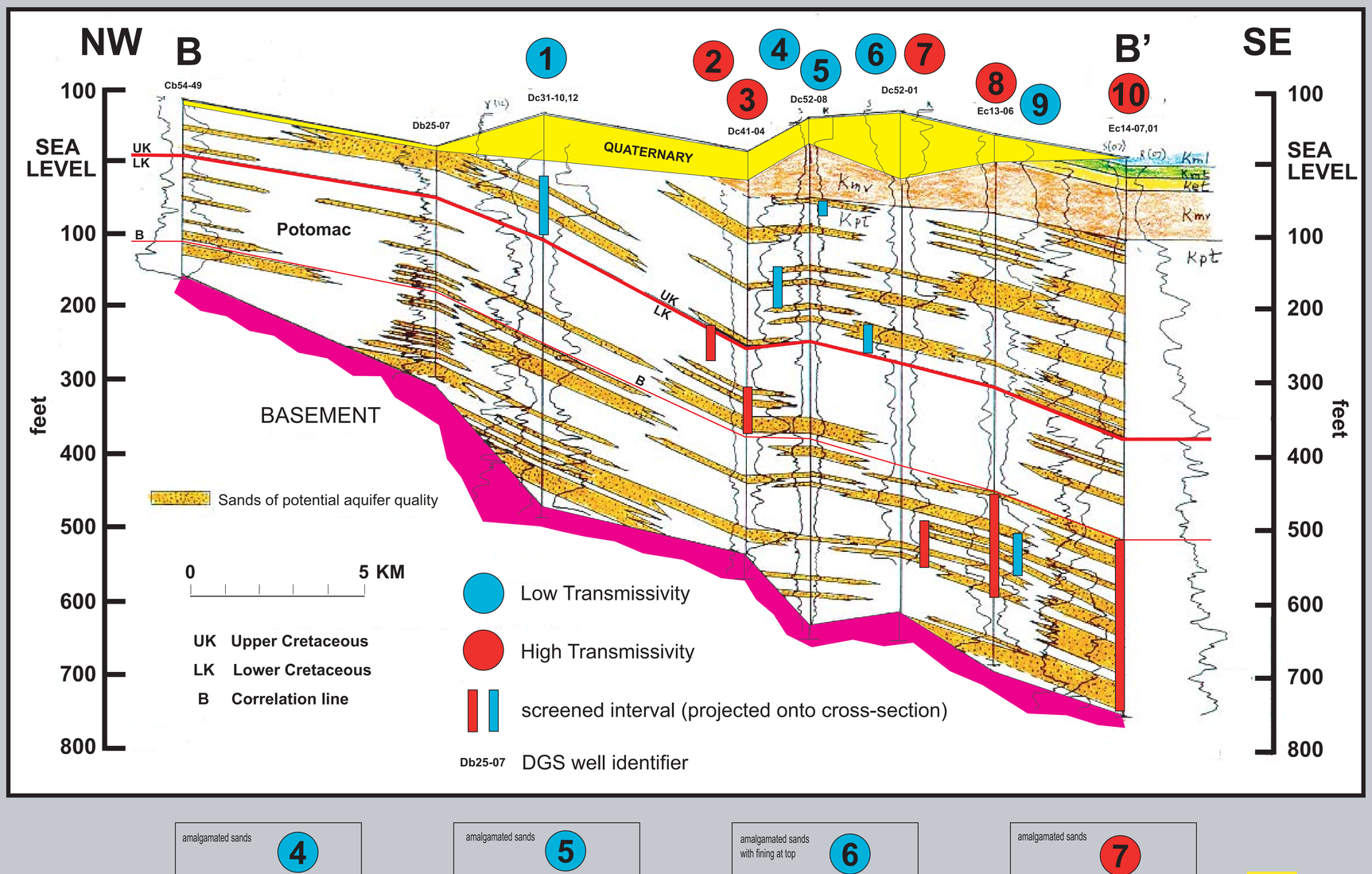


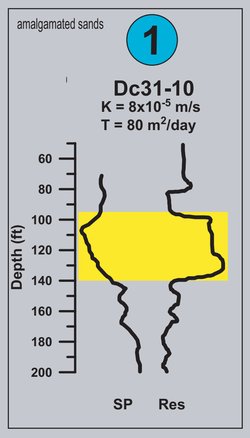
Vertical Hydraulic Conductivity from tests = 10^{-8} - 10^{-5} m/s (10^{-3} - 3 ft/day)
Highly variable (over 3 orders of magnitude range from 1 test at 3 different wells)

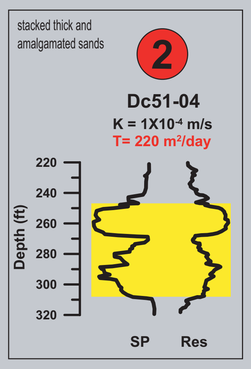


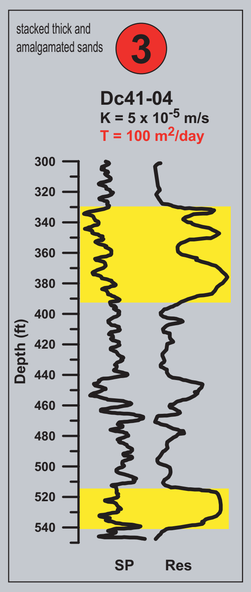
Mudrocks containing paleosols are overcompacted and are estimated to have very low local permeability (10^{-15} - 10^{-12} m/s; 10^{-10} - 10^{-7} ft/day)

Aquifer Framework

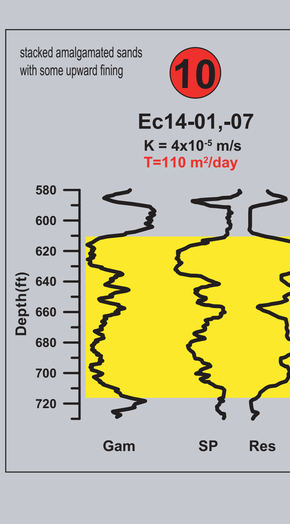


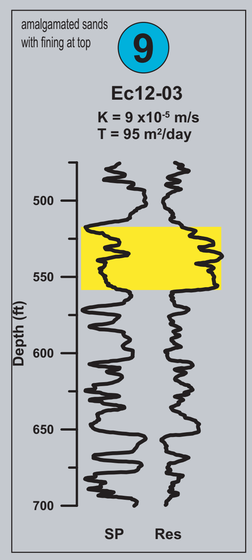




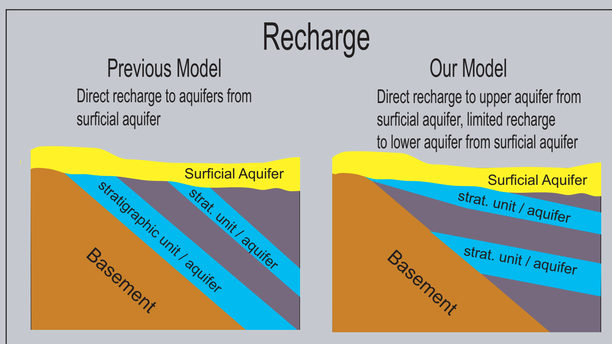


= aquifer





Recharge



Stratigraphic correlations indicate the Potomac Fm. onlaps basement. A previous aquifer model (Martin, 1984) assumed basement-parallel stratigraphy. This has signficiant implications for modeling recharge.

- Best aquifers are characterized as stacked amalgamated and thick channel sands
- Estimated 2 - 3 mile (3 - 5 kilometer) horizontal sand dimension within a stratigraphic interval
- 50 - 100 feet (15 - 30 meter) vertical sand dimension
- Highest transmissivity zones along section are in lower part of Potomac Formation, below UK / LK horizon
- Highest transmissivity is in stacked sands (e.g. near the base of the Potomac Formation in the southeast part of the cross-section)

Conclusions

- Framework developed for stratigraphic correlation in the Potomac Formation using palynology and geophysical log correlations tied to three continuous cores
- Potomac Formation onlaps basement and is increasingly truncated updip by younger formations
- Potomac Formation characterized by five facies and environments: 1) amalgamated sands (amalgamated channels), 2) thick sands (isolated channels), 3) thin sands (crevasse splay / proximal levee), 4) interlaminated sand and silt (distal levee / flood plain), 5) mottled silts and clays (weathered flood plain / paleosols)
- Major aquifers composed of stacked amalgamated and isolated channel sands
- Major aquitards composed of flood-plain silts and clays with abundant paleosols

Implications

- These interpretations of depositional environments within well-defined stratigraphic boundaries, when combined with aquifer tests and potentiometric-surface response to pumping, will increase our ability to determine the magnitudes and directions of ground-water flow.

Future Directions

- **Stratigraphy:** refine correlations based on new understanding of sedimentology; more palynology; explore paleosols, heavy minerals, and clays
- **Sedimentology:** increase areal coverage based on log characteristics; map depositional environments within sequences
- **Hydrogeology:** aquifer-test compilation and comparison with depositional-system maps, detailed study on smaller areas with aquifer tests, pumping schedules / water levels; map recharge areas (sand subcrop)

Presented at: Society for Sedimentary Geology (SEPM) Research Conference on Ancient and Modern Coastal Plain Depositional Environments: Aquifer Heterogeneity and Environmental Implications, March 24 - 27, 2002, Charleston, SC.