VOL. 1/2015

ISSN : 2355-7524

batan

PROSIDING

SEMINAR NASIONAL TEKNOLOGI ENERGI NUKLIR 2015

TEKNOLOGI NUKLIR UNTUK KEMANDIRIAN DAN KEBERLANJUTAN PEMBANGUNAN NASIONAL

Denpasar - Bali, 15 - 16 Oktober 2015

PUSAT TEKNOLOGI DAN KESELAMATAN REAKTOR NUKLIR (PTKRN)

PUSAT KAJIAN SISTEM ENERGI NUKLIR (PKSEN)

BADAN TENAGA NUKLIR NASIONAL

ISSN : 2355 – 7524

PROSIDING
SEMINAR NASIONAL
TEKNOLOGI ENERGI NUKLIR 2015

Bali, 15-16 Oktober 2015

BADAN TENAGA NUKLIR NASIONAL

Pusat Teknologi dan Keselamatan Reaktor Nuklir

Pusat Kajian Sistem Energi Nuklir

2015

 ISSN : 2355-7524

ISSN : 2355-7524

KATA PENGANTAR

Puji syukur kami panjatkan kehadirat Tuhan Yang Maha Esa, yang telah melimpahkan rahmat dan hidayah Nya sehingga Prosiding Seminar Nasional Teknologi Energi Nuklir 2015 dapat diselesaikan. Prosiding ini memuat makalah yang dipresentasikan pada Seminar Nasional Teknologi Energi Nuklir, dengan tema Kontribusi Teknologi Energi Nuklir bagi Kemandirian dan Keberlanjutan Pembanguan Nasional, yang diselenggarakan pada hari Kamis – Jumat, 15 – 16 Oktober 2015 di Gedung Pascasarjana Universitas Udayana, Denpasar, Bali. Seminar tersebut terselenggara atas kerjasama Pusat Teknologi dan Keselamatan Reaktor Nuklir (PTKRN-BATAN) dengan Pusat Kajian Sistem Energi Nuklir (PKSEN-BATAN) didukung oleh Fakultas Teknik dan Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Udayana.

Penerbitan Prosiding ini dimaksudkan untuk menyebarluaskan hasil penelitian dan pengembangan iptek energi nuklir. Diharapkan dengan terbitnya prosiding ini dapat menggalang kesinambungan komunikasi di antara para peneliti, akademisi, dan pemerhati terkait dengan iptek energi nuklir di Indonesia, dalam rangka mengantisipasi pesatnya perkembangan iptek energi nuklir di dunia.

Panitia menerima sebanyak 83 makalah teknis dari berbagai instansi. Setelah melalui seleksi dan evaluasi oleh Dewan Editor, Panitia memutuskan 77 makalah dapat diterima untuk dipresentasikan dalam Seminar Nasional Teknologi Energi Nuklir 2015. Hasil seleksi ulang dan evaluasi oleh Dewan Editor terhadap makalah yang dipresentasikan, memutuskan sebanyak 74 makalah dapat diterbitkan dalam Prosiding Seminar Nasional Teknologi Energi Nuklir 2015. Ke 74 makalah tersebut terdiri dari : 67 makalah dari BATAN, masing-masing 2 makalah dari BAPETEN dan Universitas Udayana, dan masing-masing 1 makalah dari Universitas Sriwijaya, ATK Kemenperin Yogyakarta, dan STKIP Sumedang.

Kami menyadari bahwa prosiding ini tentu saja tidak luput dari kekurangan, untuk itu segala saran dan kritik kami harapkan demi perbaikan prosiding pada terbitan tahun yang akan datang. Akhirnya kami berharap semoga prosiding ini bermanfaat bagi yang memerlukan.

Jakarta, Maret 2016

Dewan Editor

batan

KEPUTUSAN

KEPALA BADAN TENAGA NUKLIR NASIONAL

NOMOR: 77/KA/III/2015

TENTANG

PERUBAHAN LAMPIRAN KEPUTUSAN KEPALA BATAN NOMOR 41/KA/II/2015 TENTANG PENYELENGGARAAN SEMINAR NASIONAL TEKNOLOGI ENERGI NUKLIR 2015 DAN PEMBENTUKAN PANITIA

KEPALA BADAN TENAGA NUKLIR NASIONAL,

Menimbang:
a. bahwa dengan Keputusan Kepala BATAN Nomor 41/KA/II/2015 telah ditetapkan Penyelenggaraan Seminar Nasional Teknologi Energi Nuklir 2015 dan Pembentukan Panitia;
b. bahwa untuk kepentingan dinas, maka perlu mengubah Lampiran Keputusan sebagaimana dimaksud pada huruf a;

Mengingat :
1. Peraturan Presiden Nomor 46 Tahun 2013 tentang Badan Tenaga Nuklir Nasional;
2. Keputusan Presiden Nomor 72/M Tahun 2012;
3. Peraturan Kepala BATAN Nomor 14 Tahun 2013 tentang Organisasi dan Tata Kerja Badan Tenaga Nuklir Nasional sebagaimana telah diubah dengan Peraturan Kepala BATAN Nomor 16 Tahun 2014;

MEMUTUSKAN:

Menetapkan : KEPUTUSAN KEPALA BADAN TENAGA NUKLIR NASIONAL TENTANG PERUBAHAN LAMPIRAN KEPUTUSAN KEPALA BATAN NOMOR 41/KA/II/2015 TENTANG PENYELENGGARAAN SEMINAR NASIONAL TEKNOLOGI ENERGI NUKLIR 2015 DAN PEMBENTUKAN PANITIA.

KESATU	:	Mengubah Lampiran Keputusan Kepala BATAN Nomor 41/KA/II/2015 tentang Penyelenggaraan Seminar Nasional Teknologi Energi Nuklir 2015 dan Pembentukan Panitia menjadi sebagaimana tersebut dalam Lampiran Keputusan ini.
KEDUA	:	Keputusan ini mulai berlaku pada tanggal ditetapkan.

Ditetapkan di Jakarta
pada tanggal 25 Maret 2015
KEPALA BADAN TENAGA NUKLIR NASIONAL,

-ttd-

DJAROT SULISTIO WISNUBROTO

Salinan sesuai dengan aslinya,
KEPALA BIRO SUMBER DAYA MANUSIA DAN ORGANISASI,

BADAN TENAGA NUKLIR NASIONAL ★ REPUBLIK INDONESIA ★ batan

HADI SUSILO

batan

LAMPIRAN

KEPUTUSAN KEPALA BADAN TENAGA NUKLIR NASIONAL

NOMOR : 77/KA/III/2015

TANGGAL : 25 MARET 2015

SUSUNAN PANITIA PENYELENGGARA SEMINAR NASIONAL
TEKNOLOGI ENERGI NUKLIR 2015

I. Pelindung	:	Prof. Dr. Djarot Sulistio Wisnubroto	- BATAN
II. Pengarah	:	1. Dr. Taswanda Taryo, M.Sc.Eng	- BATAN
		2. Prof. Dr. dr. Ketut Suastika, SpPD KEMD	- UNUD
III. Penanggung Jawab	:	1. Dr. Geni Rina Sunaryo, M.Sc	- BATAN
		2. Ir. Yarianto Sugeng Budi Susilo, M.Si	- BATAN
		3. Drs. A. A. Raka Dalem, M.Sc (Hons)	- UNUD
		4. Prof. Ir. I Wayan Redana, M.A.Sc, Ph.D	- UNUD
IV. Penyelenggara	:		
Ketua Umum	:	Syaiful Bakhri, ST	- BATAN
Ketua Pelaksana	:	Mulya Juarsa, M.Sc	- BATAN
Wakil Ketua I	:	Drs. Sahala Maruli Lumban Raja	- BATAN
Wakil Ketua II	:	Dr. Ir. Sudi Ariyanto, M.Eng	- BATAN
Sekretaris I	:	Topan Setiadipura, S.Si, M.Si	- BATAN
Sekretaris II	:	Rr. Arum Puni Rijanti S., ST, MT	- BATAN
Bendahara I	:	Marini Landina, SE	- BATAN
Bendahara II	:	Waris Juniarsih	- BATAN
Seksi-seksi	:		
a. Acara dan Persidangan:			
		1. Dr. Julwan Hendry Purba	- BATAN
		2. Made Widyarta, ST, M.Sc, Ph.D	- UNUD
		3. Gusti Ngurah Sutapa, S.Si, M.Si	- UNUD

4. Dr. Suparman - BATAN
5. Sofia Loren Butar-Butar, ST - BATAN
6. Yuliastuti, M.Si - BATAN
7. Syamsul Ali Ikhsan - BATAN

b. Humas, Perizinan dan Informasi (*Website*):

1. Anik Purwaningsih, S.Si - BATAN
2. Drs. I Made Satriya Wibawa, M.Si - UNUD
3. Ainul Guhri, Ph.D - UNUD
4. Yeni Supriyati - BATAN
5. Mudjiono, S.Si - BATAN

c. Prosiding dan Distribusi *Reviewer*:

1. Dr. R. Mohammad Subekti - BATAN
2. Dr. Ni Made Suwatini, MS - UNUD
3. I Dewa Gede Ary Subagia, Ph.D - UNUD
4. Ir. Suwoto - BATAN
5. Wiku Lulus Widodo, M.Eng - BATAN

d. Perlengkapan dan Dokumentasi:

1. Ir. Sriyono - BATAN
2. Sunarto - BATAN
3. Kusnaedi Manguto Puasora - BATAN
4. I Ketut Putra, S.Si, M.Si -UNUD
5. I Ketut Astawa, ST, MT - UNUD

e. Konsumsi :

1. Restu Maerani, ST - BATAN
2. Meity Purwantini - BATAN
3. Dra. Ni Nyoman Ratini, M.Si - UNUD
4. Putu Lokantara, ST, MT - UNUD
5. Detty Setiawati S - BATAN

f. Umum dan Transportasi:

1. Nurul Huda, S.Si - BATAN
2. Imam Hamzah - BATAN
3. I Wayan Supardi, S.Si, M.Si - UNUD

batan

			4. Ir. Made Suarda, M.Eng	- UNUD
			5. Dian Koliana Kamal	- BATAN
g.	Protokoler	:	1. Helmi Setiawan, S.Sos	- BATAN
			2. Rahayu Kusumastuti, MT	- BATAN
h.	Eksebisi	:	1. Drs. Heru Santosa	- BATAN
			2. Sungkono	- BATAN

V. Dewan Editor :

a. Sesi Bahasa Indonesia:

Ketua	:	Dr. Ir. P. Made Udiyani, M.Si	- BATAN
Wakil Ketua	:	Ir. Djati Hoesen Salimy, M.Eng	- BATAN
Sekretaris I	:	Drs. Ign. Djoko Irianto, M.Eng	- BATAN
Sekretaris II	:	Dra. Heni Susiati, M.Si	- BATAN
Anggota	:	1. Dr. Ir. Hendro Tjahjono	- BATAN
		2. Prof. Drs. Surian Pinem, M.Si	- BATAN
		3. Dr. Jupiter Sitorus Pane, M.Sc	- BATAN
		4. Drs. Tukiran	- BATAN
		5. Dr. Camelia Panatarani, S.Si, M.Eng	- UNPAD
		6. Dr. Sidik Permana, M.Eng	- ITB
		7. Dr. Sihana	- UGM
		8. Prof. Dr. June Mellawati, S.Si	- BATAN
		9. Ir. Sriyana, MT	- BATAN
		10. Drs. Sahala Maruli Lumban Raja	- BATAN
		11. Ir. Erlan Dewita, M.Eng	- BATAN
		12. Dr. Wayan Nata Septiadi, ST, MT	- UNUD
		13. Dr. Ir. Ketut Gede Sugita, MT	- UNUD
		14. Prof. Dr. I Wayan Budiarsa Suyasa, MS	- UNUD
		15. Dr. I Wayan Gede Suharta	- UNUD

b. Sesi Bahasa Inggris:

Ketua	:	Dr. Geni Rina Sunaryo, M.Sc	- BATAN
Sekretaris	:	Dr. Julwan Hendry Purba	- BATAN
Anggota	:	1. Ir. Tagor Malem Sembiring	- BATAN
		2. Dr. Deendarlianto, ST, M.Eng	- UGM

3. Ir. I Nyoman Budiarsa, MT, Ph.D - UNUD
4. Prof. I Nyoman Suprapta Winaya, Ph.D - UNUD
5. Prof. Dr. Ing. Nandy Putra - UI
6. Prof. Dr. Eng. Zaki Su'ud - ITB
7. Dr. rer.nat. Ayi Bachtiar, S.Si - UNPAD
8. Prof. T. M. Indra Mahlia - Malaysia
9. Prof.Emeretus. Dr.Eng. Kaichiro Mishima - Japan
10. Prof. Dr. Eng. Toru Obara - Japan
11. Hwang Haito, Ph.D - China
12. Dr. Gerd Brinkmann - Germany
13. Dr. Marius Fox - South Africa
14. Dr. Ir. Heri Suyanto - UNUD
15. Dr. Ni Nyoman Rupiasih, S.Si, M.Si - UNUD
16. Dr. Alexander Agung - UGM

KEPALA BADAN TENAGA NUKLIR NASIONAL,

-ttd-

DJAROT SULISTIO WISNUBROTO

Salinan sesuai dengan aslinya,
KEPALA BIRO SUMBER DAYA MANUSIA DAN ORGANISASI,

BADAN TENAGA NUKLIR NASIONAL
REPUBLIK INDONESIA
batan

HADI SUSILO

 ISSN : 2355-7524

DAFTAR ISI

 ISSN : 2355-7524

ISSN : 2355-7524

KELOMPOK-E : Komputasi dan Instrumentasi Nuklir

ISSN : 2355-7524

 ISSN: 2355-7524

PERMEABILITY CHARACTERISTICS OF SUBSURFACE MATERIAL IN EXPERIMENTAL POWER REACTOR SITE, PUSPIPTEK-SERPONG

Heri Syaeful, Dhatu Kamajati, Adi Gunawan M., Nunik Madyaningarum
Center for Nuclear Mineral Technology, Jl. Lebak Bulus Raya No. 9,
Pasar Jumat, South Jakarta
Email: syaeful@batan.go.id

ABSTRACT

PERMEABILITY CHARACTERISTICS OF SUBSURFACE MATERIAL IN EXPERIMENTAL POWER REACTOR SITE, PUSPIPTEK-SERPONG. Permeability is defined as ability of a rock, sediment, or soil to allow pore fluid and gases to pass through it. Permeability is one important parameter in site investigation and subsurface characterization. Permeability on this research delivered from in-situ test which is falling head and packer test. Tests are implemented on 5 m of soil or rock interval in line with drilling progress. Result of test then compared with available data on physical characteristics which is lithology, gamma-ray log, and density log. Lugeon generated from calculation could also benefit for interpretation of water flow in rock and condition of rock mass discontinuities. Permeability of soil in Serpong Formation range from 2.09E-4 to 1.00E-3 cm/s, classified as medium to high, and in Bojongmanik Formation range from 5.26E-6 to 3.83E-5 cm/s, classified as very low to low. In groundwater characteristic of Serpong Formation is aquifer and Bojongmanik Formation is aquiclude. Water flow characteristic in rock dominantly is turbulent, subsequently void filling and laminar. Lugeon value of rock in DH-11 and DH-12 range from 0.3 to 1.46 or very tight to tight in term of rock mass discontinuities.

Keywords: permeability, Lugeon, aquifer, aquiclude, rock mass

ABSTRAK

KARAKTERISTIK PERMEABILITAS PADA MATERIAL BAWAH PERMUKAAN DI TAPAK REAKTOR DAYA EKSPERIMEN, PUSPIPTEK-SERPONG. *Permeabilitas didefinisikan sebagai kemampuan dari pori batuan, sedimen atau tanah untuk mengalirkan cairan pori dan gas. Permeabilitas merupakan salah satu parameter penting dalam investigasi tapak dan karakterisasi bawah permukaan. Permeabilitas pada penelitian ini dihasilkan dari uji in-situ yaitu falling head dan packer test. Tes dilaksanakan setiap interval 5 m pada tanah atau batuan sejalan dengan kemajuan pengeboran. Hasil uji kemudian dibandingkan dengan data yang tersedia untuk karakteristik fisik yaitu batuan, log sinar gamma, dan log densitas. Lugeon dihasilkan dari perhitungan juga bermanfaat untuk interpretasi dari aliran air dalam batuan dan kondisi diskontinuitas massa batuan. Permeabilitas tanah di Formasi Serpong berkisar dari 2.09E-4 sampai 1.00E-3 cm/detik, diklasifikasikan sebagai menengah dan tinggi, dan Formasi Bojongmanik berkisar dari 5.26E-6 sampai 3.83E-5 cm/detik, diklasifikasikan sebagai sangat rendah sampai rendah. Dalam karakteristik air tanah, Formasi Serpong adalah akuifer dan Formasi Bojongmanik adalah akiklud. Karakteristik aliran air dalam batuan secara dominan adalah turbulen, selanjutnya void filling dan laminar. Nilai Lugeon batuan di DH-11 dan DH-12 berkisar 0,3-1,46 atau sangat ketat untuk ketat dalam hal diskontinuitas massa batuan.*

Kata kunci: *permeabilitas, Lugeon, akuifer, akiklud, massa batuan*

 ISSN: 2355-7524

INTRODUCTION

Permeability is defined as ability of a rock, sediment, or soil to allow pore fluid and gases to pass through it [1]. Permeability is also used to called as hydraulic conductivity, and its depend on several factors: fluid viscosity, pore size distribution, grain-size distribution, void ratio, roughness of mineral particles, and degree of saturation [2]. Permeability also described based on water saturation, which is lower permeability in unsaturated soil/rock and increases rapidly with increased of degree of saturation.

Permeability is one important parameter in site investigation. Beside one of parameters in subsurface profile[3], it is also used in hazard evaluation such as analysis of liquefiable soil. Rauch describe that if gravelly soil has high permeability than it will be less prone to liquefy[4]. Rahmani is also emphasize the role of permeability data in numerical simulation of liquefaction phenomenon [5]. Other interest for the application of permeability is in analysis of radionuclide migration in the case of its release to groundwater. Bucur describe the good linear correlation between permeability and diffusion coefficient of radionuclide in geological media[6].

In-situ permeability test that is applied in this research is falling head and packer test. Falling head test has been widely used to determine the permeability of geologic material, which could be in the zone of vadose or above groundwater table or in saturated zone below groundwater table. Bagarello et al. has applied falling head method to measure field soil permeability in saturated zone[7], while Reynold applied this method for infiltration assessment in the vadose zone[8]. Packer test has also been widely and accepted as method for determination of permeability in rock zone, such as applied by Mollah et al. in design of lowering groundwater table[9], Moon in estimation of groundwater inflow rate in tunnel[10], and Syaeful and Sucipta for determination of permeability of subsurface material in site for radioactive waste disposal[11].

In the purpose on completely understand the subsurface permeability characteristic, data resulted from in-situ permeability test will be compared with other geological physical characteristics which is lithology, gamma-ray log, and density log. Permeability test performed by packer test will also generate data of Lugeon which is highly benefit in interpretation of water flow in rock, and moreover interpretation of rock mass discontinuities.

THEORY

Intrinsic or coefficient permeability usually measured with respect to air and its independent to the fluid, which is hydraulic conductivity as measure of the water flow[12]. Furthermore, coefficient of permeability described as the factor proportionality relating the rate of fluid discharge per unit of cross-sectional area to the hydraulic gradient[13].

Field permeability test conducted in the Puspiptek site divided on two methods, which is falling head and packer test. Falling head in principle is fill the tube with water then observe the drawdown of water on the basis of time and distance. Analysis result of falling head test given by formula (1) which is used for permeability determination at zone below water table[13].

$$k = \frac{r^2}{2L(t_2 - t_1)} \ln\frac{L}{r} \ln\frac{H_1}{H_2} \qquad (1)$$

where
k : the permeability of soil (cm/s)
r : the radius of the test section (cm)
L : the length of test section (cm)
t_1 : the time when test begin (second)
t_2 : the time after the test (second)
H_1 : the height of water on t_1 (cm)
H_2 : the height of water on t_2 (cm)

Packer test or Lugeon test in essence comprises the measurement of the water volume that can escape from an uncased section of borehole in given time under a given pressure. Flow is confined between known depths by means of packers. The test is used to give an approximation value of the rock mass permeability [6]. Analysis of packer test given by formula (2)[14].

$$k = \frac{Q}{2\pi \mathrm{L} \mathrm{h}} \ln\left(\frac{L}{r}\right) \qquad (2)$$

 ISSN: 2355-7524

where
k : the permeability coefficient (cm/s)
Q : the water discharge (cm^3/s)
L : the length of test section (cm)
r : the radius of the of the test section (cm)
h : the difference between height of manometer and groundwater (cm)

METHODOLOGY

Prior to field implementation of packer test, determination of maximum water pump pressure which will be applied during the test has to be first determined. Based on SNI [14], determination of maximum pump water pressure has to be based on total stress in subsurface material. The total stresses known by calculate the soil/rock overburden with water weight at each of soil layer as shown in formula (3)[2].

$$\sigma = H\gamma_w + (H_A - H)\gamma_{\text{sat}} \quad (3)$$

where
σ : total stress at the elevation of point A (kN/m^2)
γ_w : unit weight of water (kN/m^3)
γ_{sat} : saturated unit weight of soil (kN/m^3)
H_A : distance between point A and water table (m)
H : height of water table (m)

In-situ stress developed in subsurface material calculated from data of soil/rock profile, includes its bulk/saturated unit weight for each layer. Data of soil profile delivered from nearby subsurface investigation with the purpose of near surface disposal construction of radioactive waste disposal (Table 1)[15]. Subsurface site investigation composed of 5 drill-hole data which is range between 30 to 100 m in depth.

Table 1. Profile of subsurface material [15]

	Elevation (m)	**Depth to surface (m)**	**Layer thickness (m)**	**Bulk unit weight kN/m^3**	**Saturated unit weight kN/m^3**
Clay	73 to 69	0 to 4	4	14.89	18.58
Silty clay	69 to 65	4 to 8	4	-	18.20
Gravelly silt	65 to 53	8 to 20	12	-	19.39
Siltstone 2	53 to 9	20 to 64	44	-	15.98
Limestone	9 to 0	64 to 73	9	-	18.68
Siltstone 1	0 to -30	73 to 103	30	-	16.80

Permeability test conducted in two drill hole for the depth of 100 m each. Test conducted on every 5 m interval or every 5 m drill hole advanced. Permeability test in soil performed by falling head method, while in rock by packer test method. Formula used in calculation of the data obtained from field test will use the formula of (1) or (2) adjusted to the method applied. In the purpose of classification, permeability coefficient or hydraulic conductivity could be classified as very low to very high. Furthermore, it also could be applied in interpretation of rock mass discontinuities (Table 2).

Table 2. Hydraulic conductivity classification, Lugeon, and interpretation of rock mass discontinuities[16]

Hydraulic Conductivity Range (cm/sec)	Classification	Lugeon Range	Condition of Rock Mass Discontinuities
$< 1 \times 10^{-5}$	Very Low	<1	Very tight
1×10^{-5} - 6×10^{-5}	Low	1-5	Tight
6×10^{-5} - 2×10^{-4}	Moderate	5-15	Few partly open
2×10^{-4} - 6×10^{-4}	Medium	15-50	Some open
6×10^{-4} - 1×10^{-3}	High	50-100	Many open
$> 1 \times 10^{-3}$	Very High	>100	Open closely spaced or voids

Lugeon data resulted from packer permeability test could be benefit in interpretation of water flow characteristics in soil and rock as described by Houlsby in Rozo[16]. Interpretation of flow characteristic based on computed Lugeon value in each stages of permeability packer test. Flow characteristics could be divided on laminar, turbulent, dilation, wash-out, and void-filling (Figure 1).

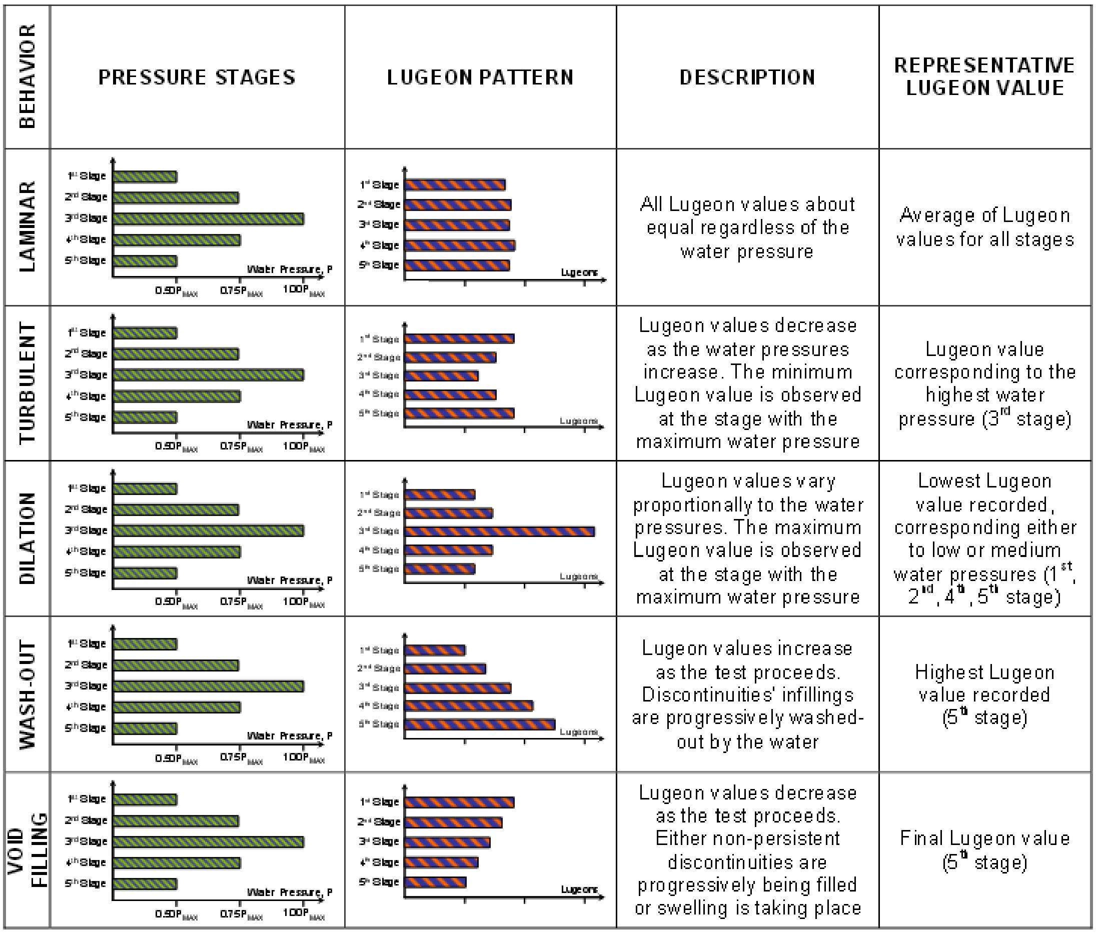

Figure 1. Interpretation of water flow characteristic based on Lugeon[16]

RESULT AND DISCUSSION

Site interest in Puspiptek, Serpong located in boundary between geological formation of Serpong and Bojongmanik. According to Turkandi,[17] Bojongmanik Formation (Fm) is Middle Miocene in age composed by alternating sandstone and claystone, with limestone intercalating, and Serpong Fm composed by alternating conglomerate, sandstone, siltstone, and claystone with plant material pumice conglomerate (Figure 2). Lithology in subsurface material as described in Syaeful et al. [15] composed by clay as residual deposit, silty clay, and gravelly clay grouped into Serpong Fm which is river deposit**.** Depth of Serpong Fm in average is 20 m. Below Serpong Fm is Bojongmanik Fm composed dominantly by intercalation of siltstone and claystone, with minor sandstone and limestone.

 ISSN: 2355-7524

Calculation of the in-situ stress in subsurface and determination of water pump pressure is the first stage prior to conducting field packer permeability test. Method in calculation using formula (3) with basis of subsurface material as described in Table 1. Total stress defined here is accumulation of stress due to soil/rock overburden and groundwater pressure. Unit weight selected is bulk unit weight for soil layer above groundwater and saturated unit weight for soil/rock layer below groundwater level. Total stress of layer will be increased in depth as a function of overburden pressure of each layer. Groundwater level measured by dipmeter shown the number of 5.15 m in depth. After in-situ stress profile known, then it is multiplied by 0.23 as basis for determination of water pump pressure (Figure 3).

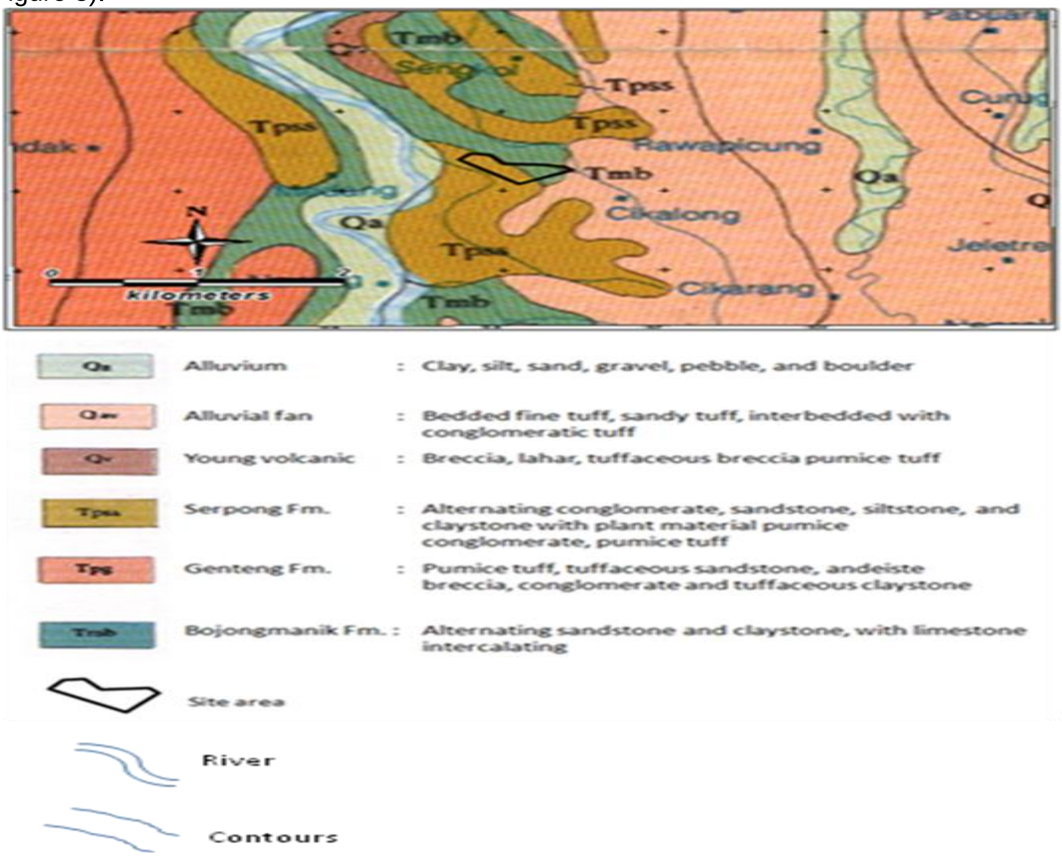

Figure 2. Geological map of Puspiptek, Serpong[17]

Falling head test conducted on every 5 m of drilling progress in soil layer. Prior to the test, drill rod is lifted from drillhole leaving drillhole with casing inserted. The NQ size casing is set in order to make the zone of tested soil layer uncased to allow the water flown into layer. Test conducted by fill the water until reach the top most part of casing and observe the water falling in some unit of time. The time defined for observation is 60 second for each of test. The test is repeated for 10 times and calculates its average value as permeability of the section. Intended for permeability calculation purposes, data such as height of casing, groundwater level, casing size, and inclination are also measured.

Packer test conducted on the same interval as falling head test. Packer used in field test is mechanical packer which is made from rubber. Mechanical packer expanded by pushing the drill rod to the bottom of drillhole, which is the logical reason it is only applicable for rock layer. Theoretically, and through physical observation to the material used for packer, mechanical packer is stronger than air packer in term of packing ability to resist water pressure. The water pump pressure defined based on calculation of 0.23 from total stress (Figure 3). Water pump pressure used in in-situ packer test ranging from 2.5 to 4 kg/cm^2. As described British Standard [15], reason of determination of maximum water pressure is to prevent uplift in the ground or break the packer seal. During in-situ test, data of lithology, depth of measurement, height of manometer, groundwater level, diameter, and water discharge is noted.

 ISSN: 2355-7524

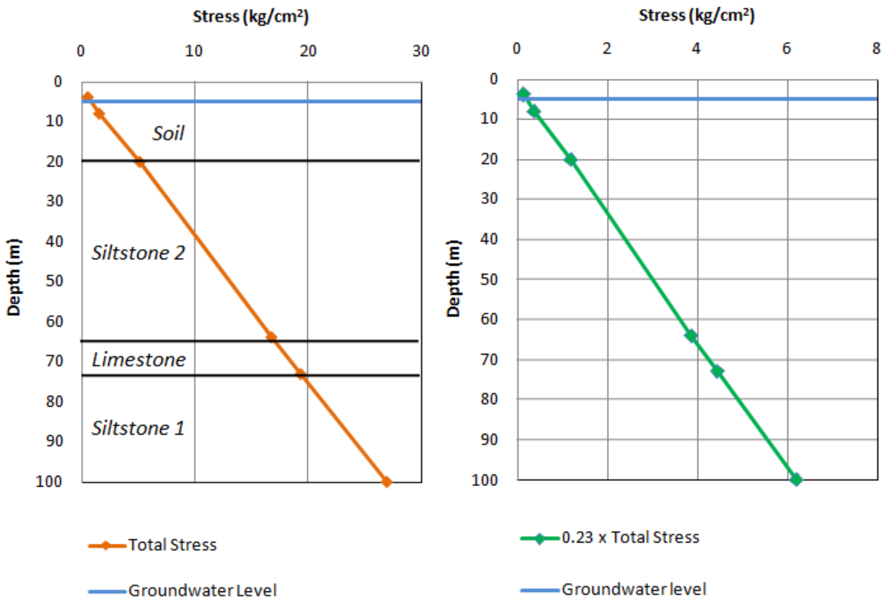

Figure 3. Calculation of total stress (left) and 0.23 from total stress as basis for determination of water pump pressure (right)

After field acquisition data, permeability of each zone of interest is calculated using formula adjusted to the method applied. All permeability value generated by both of methods is assumed and treated as comparable, or methods applied will not produce different result. The simplest method in interpretation of permeability is in the term of soil/rock layer role in groundwater system. Two important function related to role in groundwater system is as an aquifer or as an aquiclude. Aquiclude defined as low permeability unit that forms either the upper of lower boundary of a groundwater system, while aquifer defined as rock or sediment in a formation that is saturated and sufficiently permeable to transmit significant quantities of water[18].

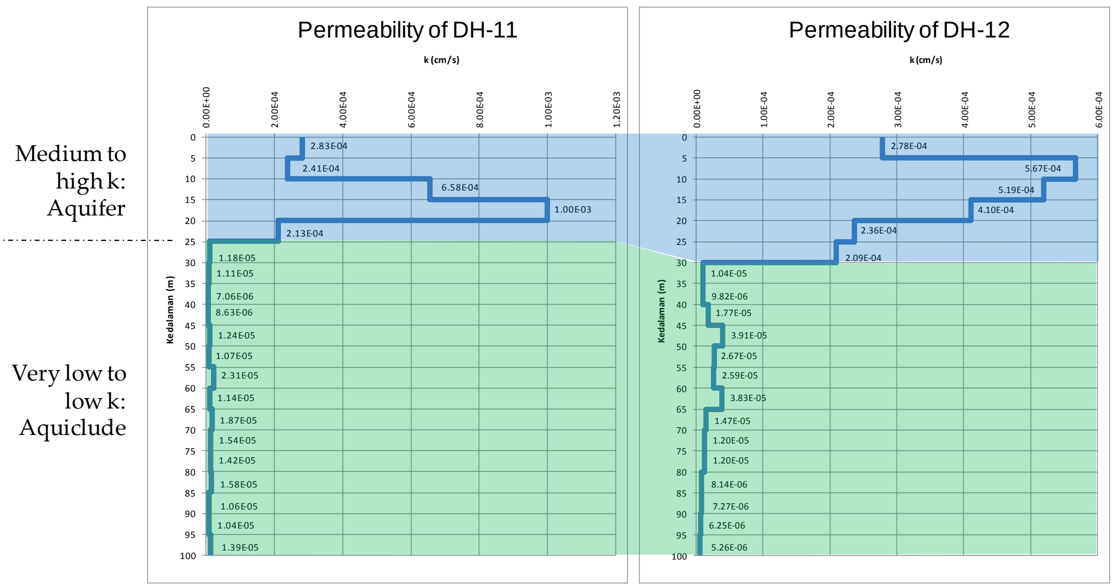

Figure 4. Result of permeability test in DH-11 and DH-12 and groundwater system interpretation

Permeability in DH-11 shows high value between 2.13E-04 to 1.00E-03 cm/s which is interpreted as zone of aquifer in the depth between 0 to 25, and extremely lower permeability value of 7.06E-06 to 2.31E-06 cm/s as an aquiclude in depth between 25 to 100 m. In DH-12 drillhole, aquifer zone identified in the depth of 0 to 30 m with permeability ranging from 2.09E-04 to 5.67E-04 cm/s, and aquiclude in the depth between 30 to 100 m with permeability range from 5.26E-06 to 3.91E-05 cm/s (Figure 4).

 ISSN: 2355-7524

In visual core interpretation, Serpong Fm in DH-11 and DH-12 is silty clay, sand, and gravelly sand in the base of formation. In DH-12 boundary between formation is very clear by existence of lenses basalt conglomerate composed by unconsolidated gravelly sand as matrix and rounded volcanic rock as fragment. Color of Serpong Fm generally is brighter than Bojongmanik Fm due to dissimilarity of depositional environment. Soil is semi-consolidated, highly to slightly weathered, light brownish to light grey. Bojongmanik Fm is generally dark grey in color, composed by intercalation of claystone, siltstone, sandstone and limestone, hard to very hard (Figure 5).

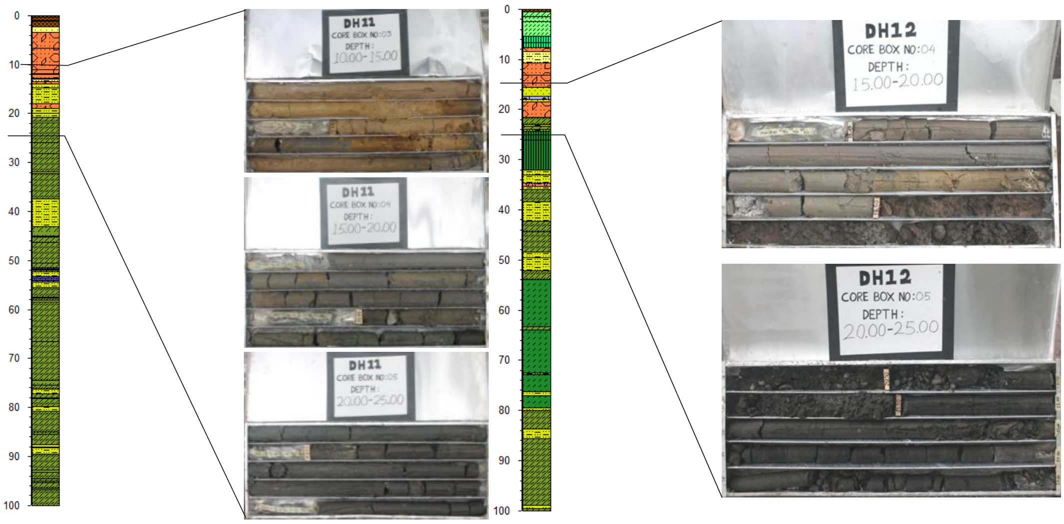

Figure 5. Drill core of DH-11 (left) and DH-12 (right) in the transition zone of Serpong Fm to Bojongmanik Fm

Further analysis of comparison between permeability and gamma-ray log, or permeability with density log expected generated a more detail physical properties of subsurface material in the site. Gamma-ray log provide a continuous record of natural gamma radiation emitted by geologic materials, it is generally reveal the presence of shale or clay beds because clay minerals commonly contain potassium [19]. Density log measures response of geologic medium to bombardment by gamma radiation, strata with high bulk densities will produce lower count in detector. The primary use of the density log is determining bulk density [19]. Field acquisition of gamma-ray and density data carry out by Mountsopris MGX-II in NQ size casing. In density log acquisition, source of radiation is Cs-137.

Visual-manual or direct interpretation of lithology from DH-11 drill core shown clear boundary between Serpong Fm and Bojongmanik Fm, in around 20 m, gamma-ray interpretation defined coarsening-upward facies as boundary between formation which is also clearly shown in density log in the depth of around 30 m. Sharp deflection of density is very good indicator of boundary between formation and its avoid misinterpretation of rock by visual interpretation due to formation of mud-cake as blanket in drill core. Density log of DH-11 shows sharp deflection from 2.586 gr/cm3 in the depth of 30 m to around 2.582 gr/cm3. Other explanation of this phenomenon is from existence of slumping of claystone to paleo-channel of Serpong Fm prior to or during its deposition. On the other hand, permeability show clear boundary in 25 m which propose new boundary between geological formations (Figure 6). Until now, no clear logic explanation for this inconsistent boundary.

 ISSN: 2355-7524

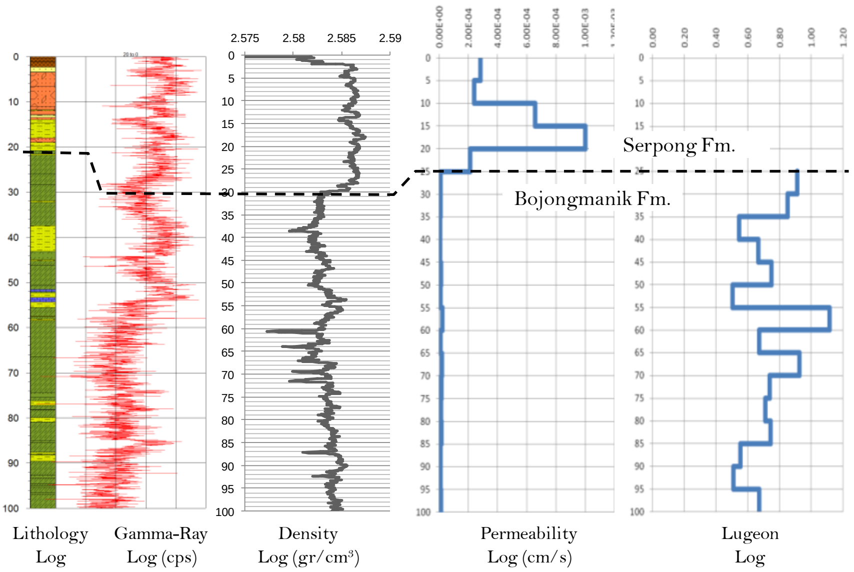

Figure 6. Correlation between lithology, gamma-ray, density, permeability, and lugeon in DH-11

In DH-12 boundary between lithology, gamma-ray and density is more consistent. Visual manual interpretation of basalt conglomerate and its change to sand is shown in gamma-ray log as fining upward facies in 2 m of length followed by coarsening upward facies for up to 4 m which is sandy gravel and sand in drill core interpretation. Permeability boundary which is interpreted from permeability is in 30 m of depth. Permeability is decreased from around 2E-04 cm/s to less than 1E-05 cm/s (Figure 7). Possible explanation of this phenomenon is leakage which is occur during field test. Different with packer test method, falling head used only the drill casing as boundary and as impermeable material to cover geological layer which is not measured. Space between casing and drillhole could be an escape zone of water and made the infiltrated water higher than it should.

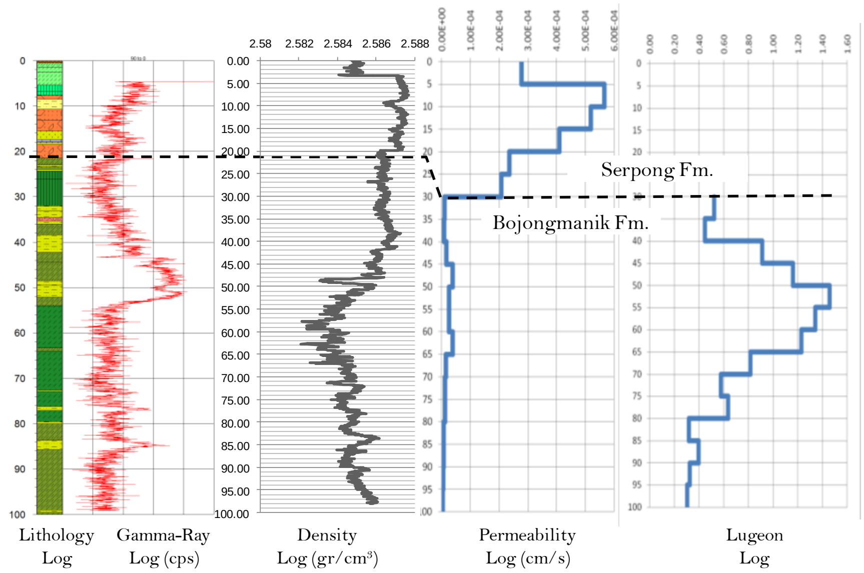

Figure 7. Correlation between lithology, gamma-ray, density, permeability, and lugeon in DH-12

DH-11 and DH-12 is 30 m in distance, correlation between permeability in DH-11 and DH-12 conducted to understand flow characteristic in subsurface material which is assumed governed by permeability value (Figure 8). Correlation conducted by inverse distance weighted method, with interval contour 0.4E-4 cm/s. Strong correlation shown between density and permeability in DH-11 to DH-12. Permeability contour slope toward DH-

ISSN: 2355-7524

11 follow the slope of density as a function of thickness of geological formation. Thickness of Serpong Fm in DH-11 is 30 m and in DH-12 is 20 m. Slightly different of permeability in the depth of 40 to 70 m in DH-12 also shown in contour correlation equal with pattern of density in DH-12 which is slightly decreased.

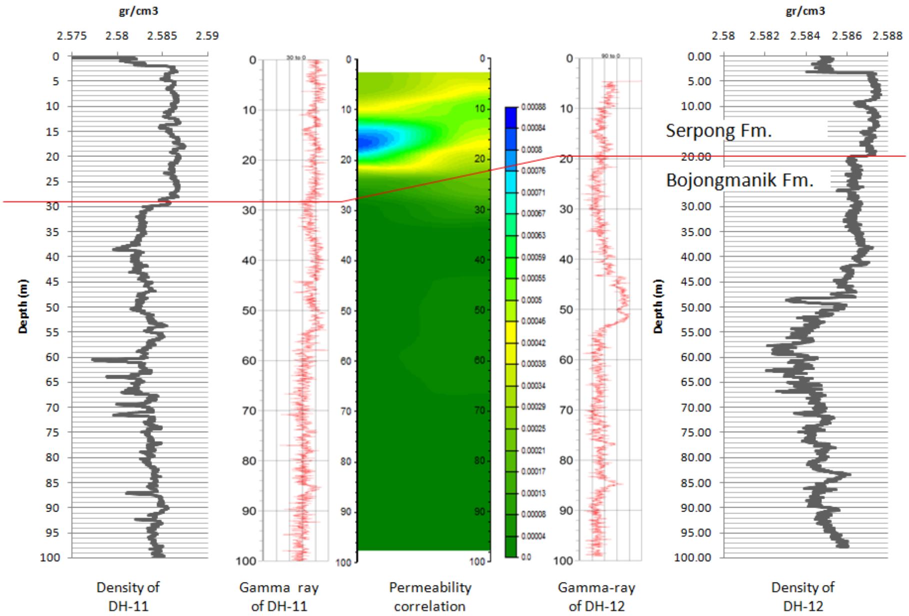

Figure 8. Correlation between permeability, gamma-ray log, and density log of DH-11 and DH-12

Moreover permeability Lugeon resulted from calculation of packer test result is very important data. Lugeon has benefit for interpretation of water flow characteristic in rock. Interpretation is based on Lugeon pattern resulted from each stage of packer permeability test. Water flow in rock could be interpreted as laminar, turbulent, dilation, wash-out and void filling. In DH-11 water flow interpreted as laminar in depth 25-45 m, Lugeon assigned as average value on each test, in 45-50 m water flow is turbulent, Lugeon assigned in highest pressure or in 3rd stage, in depth 50-55 m water flow is void filling, Lugeon value assigned at the last or 5th stage, in depth 55-60 m water flow is turbulent, Lugeon values assigned at 3rd stage, in depth 60-65 water flow is void filling, Lugeon assigned at 5th stage, and in depth 65-100 water flow is turbulent, Lugeon values assigned at 3rd stage. Based on Lugeon value as proposed by Houlsby in Rozo [16], rock in DH-11 classified as very tight with Lugeon less than 1 except in depth 55-60 m where Lugeon reach 1.12 or classified as tight (Figure 9).

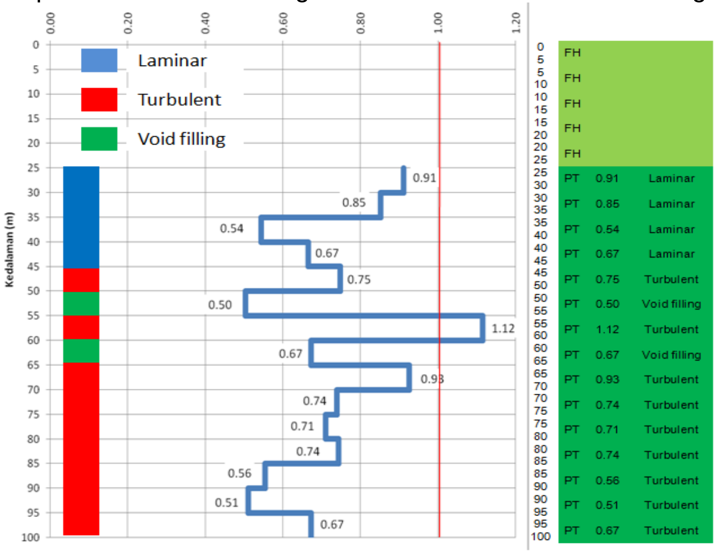

Figure 9. Water flow interpretation and assigned Lugeon value in DH-11. (Note: FH is falling head, PT is Packer Test)

 ISSN: 2355-7524

Houlsby in Rozo[16] described that laminar flow in rock correspond to characteristic of rock mass and its low permeability level, turbulent correspond to rock mass characteristics exhibiting partly open to moderately wide cracks, and void filling indicates either water progressively fill discontinuities or swelling occur in discontinuities or fines flow slowly into discontinuities building up cake layer. In DH-12 water flow in depth 30-40 m is void filling, in depth 40-95 m water flow is turbulent, and in depth 95-100 m water flow is void filling. Based on Lugeon value, rock in DH-12 classified as very tight in depth 30-45 m, tight in 45-65 m, and very tight in 65 to 100 m (Figure 10).

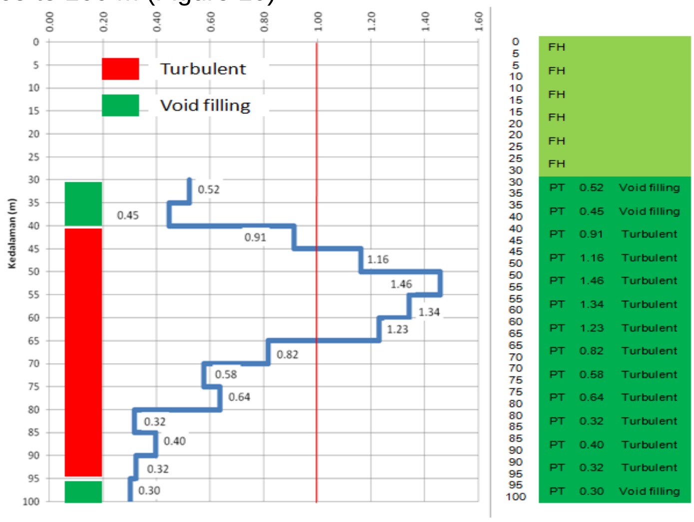

Figure 10. Water flow interpretation and assigned Lugeon value in DH-12. (Note: FH is falling head, PT is Packer Test)

CONCLUSION

Geology of ground subsurface in Puspiptek site is Serpong Fm to the depth of 25-30 m and Bojongmanik Fm below Serpong Fm up to 100 m. Permeabiliy of soil in Serpong Fm is medium to high and in Bojongmanik Fm is very low to low. In the groundwater system, Serpong Fm classified as aquifer and Bojongmanik Fm classified as aquiclude. Water flow characteristic in rock dominantly is turbulent, subsequently void filling and laminar. Lugeon value of rock in DH-11 and DH-12 is very tight to tight in term of rock mass discontinuities.

Gamma-ray and density data is highly benefit in interpretation of soil/rock mass characteristic and also for detail correlation between drillhole, for example in DH-11 sharp density boundary between Serpong Fm and Bojongmanik Fm observed in depth of 20 m. Gamma-ray data could be used for facies interpretation and analysis to understand the depositional environment of ground subsurface. In term of engineering geology density data has more benefit than gamma-ray because it is related directly with physical properties of soil/rock layer.

REFERENCES

1. SMITH, J., “The Facts On File Dictionary of Earth Science-Revised Edition”, New York: USA (2006).
2. DAS, B.M., “Principles of Geotechnical Engineering”, 7th Edition, Stamford, USA (2010).
3. IAEA SAFETY GUIDE NS-G-3.6, “Geotechnical Aspects of Site Evaluation and Foundation for Nuclear Power Plant”, Vienna (2004).
4. RAUCH, A.F.,”EPOLLS: An Empirical Method for Predicting Surface Displacements Due to Liquefaction-Induced Lateral Spreading in Earthquake”, PhD dissertation Virginia Polytechnic Institute and State University, VA (1997).
5. RAHMANI, A., FARE, O.G., and PAK, A., Investigation of the influence of permeability coefficient on the numerical modeling of the liquefaction phenomenon. Scientia Iranica, Vol.19(2), pp.179-187 (2012)
6. BUCUR, C., OLTEANU, M., and PAVELESCU, M., “Radionuclide Diffusion in Geological Media”, Romanian Journal of Physics, Vol.51, pp.469-478 (2005).
7. BAGARELLO, V., ASARO, F.D., IOVINO, M., “A field assessment of the Simplified Falling Head technique to measure the saturated soil hydraulic conductivity”, Geoderma, Vol.187-188: pp.49-58 (2012)

8. REYNOLDS, W.D., "An assessment of borehole infiltration analyses for measuring field-saturated hydraulic conductivity in the vadose zone", Engineering Geology, Vol.159, pp. 119-130 (2013).
9. MOLLAH, M.A., SAYED, S.A.S., "Assessment of in-situ permeability with emphasis on packer testing in Kuwait:, Engineering Geology, Vol.39, pp.217-231 (1995)
10. MOON, J.S., 2011, "Representativeness of jointed rock mass hydraulic conductivity obtained from packer tests for tunnel inflow rate estimate", International Journal of Rock Mechanics & Mining Sciences, Vol.48, pp.836-844 (2011)
11. SYAEFUL, H., and SUCIPTA, "Penentuan Koefisien Hidraulik pada Tapak NSD, Serpong, berdasarkan Metoda Uji Permeabilitas In-Situ", Eksplorium, Vol.34(1), pp.35-50 (2013).
12. BRITISH STANDARD BS 5930:1999, "Code of Practice for Site Investigation", British Standard (1999).
13. DEPARTMENT OF NAVY, "Soil Mechanics, Design Manual 7.01", Naval Facility Engineering Command (NAVFAC), Washington (1971).
14. STANDAR NASIONAL INDONESIA (SNI), Revisi SNI 03-2411-1991, "Cara Uji Kelulusan Air Bertekanan di Lapangan" Badan Standardisasi Nasional, Bandung (2006).
15. SYAEFUL, H., SUCIPTA, and SADISUN, I.A., "Studi Geologi Teknik Tapak Penyimpanan Limbah Radioaktif (LRA) Demo Plant Tipe NSD Kedalaman Menengah di Puspiptek Serpong", Eksplorium, Vol.35(1), pp.13-28 (2014)
16. ROZO, C.Q., "Lugeon Test Interpretation-Revisited", Proceeding of 30th Annual United States Society on Dams Conference, Sacramento, California (2010).
17. TURKANDI, T., SIDARTO, AGUSTIYANTO, D.A., and HADIWIDJOYO, M.M.P., Geological Map of Jakarta and Kepulauan Seribu Quadrangle, Java, Geological Research and Development Center (PPPG), Bandung (1992).
18. U.S. ARMY CORPS OF ENGINEERS EM 1110-2-1421, "Groundwater Hydrology", Washington (1999).
19. U.S. DEPARTMENT OF INTERIOR – BUREAU OF RECLAMATION, "Engineering Geology Field Manual", Second Edition, Vol.2 (2001).