Geology. — *"Facts leading to trace out the motion and the origin of the underground water in our sea-provinces"*. By Prof. EUG. DUBOIS. (Communicated by Prof. H. W. BAKHUIS ROOZEBOOM).

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As to the origin and the condition of the underground water in our low-lands, we are, as yet, almost entirely in the dark; facts, that might throw light on the subject, are almost entirely lacking.

The hazardous suppositions made on the subject by some, and the extraordinary caution, which others thought necessary in practice, prove this. Only lately DARAPSKY, in a dictatorially written article, held forth that even now rivers of former geological periods follow their very same channels, but now as underground streams. The underground water he considered as almost exclusively river-water [1]).

Others have admitted powerful artesian currents from the eastern high-land, without any decided facts supporting that opinion. Again others fancied to have found the explanation in VOLGER's hypothesis, on the condensation of vapour in the ground; a hypothesis, refuted already a long time ago by no less an authority than HANN [2]). A single phenomenon observed in one of the East-Frisian Islands, already years ago observed in our own country, and explained, but now forgotten, led some to imagine possibilities, as to the sea threatening us also from below, a thing which filled them with anxiety. Not to mention altogether absurd and physically impossible suppositions.

However it appeared to me that an earnest searching for facts, could not but bring to light something that would give us a clue, further to find our way in this important question, important both in a scientific and a practical respect. Indeed, thanks to the kindness I met from different sides, I was enabled, during these latter months, to make a large number of observations and to collect facts which show forth, in outline, the direction, the origin and the general condition of the underground water in the main part of our low-lands.

Since it will take some time fully to work out the results obtained, the present circumstances make it desirable I think, already now, in this short communication, to make known the most important of

[1]) L. DARAPSKY, Die Trinkwasserfrage in Amsterdam. Journal für Gasbeleuchtung und Wasserversorgung. 46 Jahrgang, p. 468, sqq. (1903).

[2]) J. HANN, Zeitschrift für Meteorologie, 1880, p. 482—486.

them. My researches were principally limited to the southern part of the North-Holland low-lands, including the dunes, and the adjacent parts of the provinces of Utrecht and of South-Holland. It is a matter of course that also here I had to limit myself to the chief points of the question.

In the last decennia, hundreds of borings have been done in the polders, in the dunes and in the area between them by the corps of military engineers and by others, with the object of making fortifications or of obtaining fresh water. Down to a certain depth, the constitution of the soil is consequently pretty well known, and some deeper borings have tolerably well acquainted us also with the constitution of the soil at greater depth. Sand is the chief substance, alternating with beds of always very impure clay. Close to the surface, pretty generally, a zone is found of clayey substances, (the well-known "old sea-clay" of STARING), over considerable areas, covered with a layer of peat, which clay, in the dunes, where that peat is generally lacking, is covered with blown sand. Under the finer sand of the upper-soil, often mixed with clay, in which occur, in large areas, deeper layers of peat, there is a zone of coarse-grained, often gravelly sand, not unfrequently containing pebbles. In the west of the mentioned region, the top of that zone lies about 30 M. ÷ A P. deep, or a few metres higher; in the east, near Aalsmeer, Sloten, Amstelveen, Mijdrecht, Wilnis, Oudhuizen, it rises to 16 or 14 M. ÷ A.P.; near Muiden and Nigtevecht as high as 10 or 8 M. ÷ A.P. and its reaches the surface further east. Under Amsterdam and both south-east and north-east of it, the soil, on the whole, is much richer in clay.

Also at greater depths, clay-beds occur, but never as unbroken layers, extending over great distances; the most regular zone is after all that of the so-called old sea-clay, near the surface. It is besides of importance, that near our eastern frontiers much older formations come to the surface, than have been found, some hundreds of metres deep, under the lowlying lands in the west. This in itself is a reason not to expect artesian water, from Germany, in our western sea-provinces, to some hundreds of metres below the surface, at least.

Of great significance for the problem is also the fact that more or less pure clay rarely occurs. What is considered as such, on further examination, (washing of a number of samples of different origin, and especially chemical analysis, which analysis Dr. N. SCHOORL was kind enough to do at my request) proved to consist for only one third of clay at the most, generally for much less, even for only

one seventeenth. The investigations by Prof. SPRING [1]) have proved the fact that, and the reason why, even very thick layers of impure clay, e. g. the *limon supérieur de la Hesbaye*, let through water. What then must we think of our clay, which, though technicians will call it impermeable or "rich clay", likewise, for the greater part, consists of sand!

The chemical analysis of specimens of the fattest clay-sorts selected from their outward look, (a large number of such specimens being at my disposal from a variety of borings) showed the real clay percentage to consist of less than *a third*: at Sloten (boring IV. 2, at 4 M. ÷ A.P.) and at Uitgeest (Station, at 43 M. ÷ A.P.). Of about *a fourth*: at Hoofddorp, Haarlemmermeer (at 6 M. and also at 34 M. ÷ A.P.); at Amsterdam (Dairy at the Prinsengracht, at 9 M. ÷A.P.) and in the dunes, 3 K.M. west of Santpoort (at 40 M. ÷A.P.). Of about *a fifth*: at Amsterdam, (Dairy in the Second Spaarndammer Dwarsstraat, at 3.5 M. ÷ A.P.); at Harlem (Hagestraat, at 14 M. ÷A.P.); at Hillegom (Treslong, at 14 M. ÷ A.P.); at Beverwijk (Middle of Breestraat, at 19 M. ÷ A.P.); at Alkmaar (Station, at 22 M. ÷ A.P); in the northern part of the Watergraafsmeer polder (near the Oosterrailroad, at 35 M. ÷ A.P.); at Katwijk (875 M. South-West of the water-tower of the Leyden waterworks, at 1.6 M. ÷ A.P.). Of about *a sixth*: at Sloten (boring III. 1, at 5.50 M. ÷ A.P.) and at Eertdenkoning, in the west of the Haarlemmermeer polder (at 19.5 M. ÷A.P.). Of about *a seventh*: at Velsen (near Rosenstein, at 2.50 M. ÷ A.P.); at Katwijk (in the same borings, at 3.8 M. ÷ A.P.). *An eighth* to *a ninth*: at Beverwijk in the same borings at 5 M. ÷ A.P.); at Amsterdam (Prinsengracht, at 6 M. ÷ A.P.) and in the Koningsduin near Castricum (at 32 M. ÷ A.P.). Of less than *a tenth*: at Driehuis (Nunnery, at 18 M. ÷ A. P.). Of about *a fifteenth*: at Amsterdam (Second Spaarndammer Dwarsstraat, at 62 M ÷ A.P.); at Hillegom (Treslong, at 4 M. ÷ A.P.). Of about *a seventeenth*: in the Watergraafsmeer polder (at 8 M. ÷ A.P.). No clay at all, at Amsterdam (Second Spaarndammer Dwarsstraat, at 43 M. ÷ A.P.). The last specimen, looking like fine-sandy clay, proved to consist of sandy calcareous tufa with 77% $CaCO_3$.

As to peat, experiments have shown to me that its impermeableness

[1]) W. SPRING, Quelques expériences sur la perméabilité de l'argile. Annales de la Société géologique de Belgique. Tome 28, p. 117—127 (1901), and: Recherches expérimentales sur la filtration et la pénétration de l'eau dans le sable et le limon. Ibid. Tome 29, p. 17—48, 1892). Compare also the report of H. RABOZÉE on those investigations in: Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie. Tome 16, p. 269—295, (1902).

is equal to that of sandy clay, but that in another respect, it is very different from clay, i.e. in its water-containing capacity. Whereas clay, like sand, can contain water for scarcely more than a third of the volume of the dry substance, non-compressed peat can do so many times over. Peat of the Rieker polder, near Sloten, on the territory of the military water-works, was found to have a capacity of holding water, nine times the volume of the dry peat; and the water in it can, although slowly, yet freely move.

On the whole we have to deal with an upper-soil of finer, often clayey sand water, and on which or in which, in most places, enormous water-reservoirs occur: the peat beds, for even the compressed peat contains still a large quantity of water. In the colder (rainy) seasons the upper peat layers are not only always kept filled with fresh water, but they can, though slowly, provide lower regions from their water-store; and along with the water, no doubt with carbonic acid, which deep below will dissolve iron and chalk; and methane which, in the same way as carbonic acid, the more easily dissolves, the higher the pressure is. Deep down the latter product of decaying organic matter, cannot be formed, on account of the absence of bacteria.

Those upper-layers, little permeable, more or less shut off the zone of gravelly coarse-grained sand which at the bottom, in a similar way but much more imperfectly, in its turn is shut off by the irregular beds of impure clay and fine-grained sand, occurring there. Under those conditions the *vertical* motion of the water, must on the whole be difficult; at one place more and at the other less, according to clay or sand locally prevailing and in proportion to the latter being finer- or coarser-grained, whereas in the coarse-grained medium zone or zones, *horizontal* motion is comparatively easy; that medium zone is therefore the great channel, and in extracting underground water this "water-vein" is generally found at about 30 M. $\div$ A.P. or a little deeper still.

That indeed below that depth the underground water has an easy horizontal passage, appears from the fact, that the height to which the water ascends in tube-wells, driven below the upper-edge of the coarse-grained bed, falls but little; whereas higher up in the fine-grained sand, it nearly always is considerably higher, (i.e. excepting the deep polders, where the deep water will naturally rise above the surface of the soil).

As to fixing the direction in which the deep underground water moves, a thing that will enable us to inquire after the existence of those currents, supposed by some, and also the origin of the underground

water, the means to do so, although hardly ever applied, are evident. Just as on the surface, it is the law of gravitation that also deep below, gives to the water its horizontal course. The direction of that motion, as caused by gravitation, can be demonstrated from the inclination of the pression-line of the water, deep below, for that motion can happen only from spots under greater, to those of smaller pression. The vertical motion, under any given constitution of the soil, can, as a rule, be inferred from the positive or negative character of the pression below, with respect to the level of the water on the surface.

When the water from the underground, freely rising in a tube-well, remains below the level of that in the upper soil, that vertical motion can take place only in a downward direction — if at any rate, then and there, a motion in a vertical direction on the whole is possible, which is mostly the case. When, on the other hand, the level of the water, in the tube-well rises higher than that of the surface-water, as is the case in the deep polders, vertical motion in a somewhat permeable soil, can take place only in an upward direction. The quantity of chlorides in the water, determined as chlorine, furnishes us with an other indication of the direction of that vertical motion.

So the observation of the height to which the water ascends in the tube-wells and the mutual comparison of the same, can teach us much as to the direction in which the water moves. A great number of those observations have enabled me to ascertain, that also deep below, the motion of the underground water (uninfluenced though it remains by small irregularities), depends on the shape of the surface. In short, the direction is from the dunes to the lower regions; from the higher to the deeper polders, and any great unevenness of the surface, makes its influence felt, already at a considerable distance. In the dunes the deep underground water is under the highest pressure; in the deepest polders it ascends in the tube-wells to a level some metres lower, although there it wells up above the ground. Near a low-lying polder the water falls also in very deep wells. So not only near the surface, but also deep below, there is a motion from the dunes to those polders and also from the higher to the lower polders.

Before communicating the observations, on which those results are founded, I must specially state, that there are influences, which for a time may more or less change the pression of the water in the underground, as it appears from the rise or fall in the wells. In the first place must be mentioned: rains, which make their influence felt

almost immediately, which influence is far more powerful than any other. After the heavy rains in the fourth week of April 1903, a number of deep wells on being sounded (April 27th) showed a higher level of 0.18 to 0.20 M. A week later it had sunk about 0.06 M., and only after the dry latter half of May, towards the end of that month, it was again what it had been towards the end of April, before the heavy rains. The rising of the deep well-water, immediately after much rain, may be in part the result of the greater pressure of the upper-soil. In the same way, a train passing over the railway-dike in the Watergraafsmeer polder, for a moment raised the water 7 m.m. in a deep well, at a distance of 18 M., which well was 34.5 M. beneath the surface of the polder. Principally the rain will increase the hydrostatic pression. In the second place, changes in the pression of the atmosphere have a passing influence on the level of the water in deep wells. Those changes make themselves felt at once, but that natural barometer is an imperfect one; the effect of the changes in the atmospheric pression soon disappears. For some hours however millimeters rising or falling of the quicksilver have their equivalent in centimeters on the watergauge.

In the third place the low and the high tide of the sea, exercise a negative or a positive pression on the deep underground water, i. e. on those spots, which are not too far from the sea (3 or 4 K. M. seems to be the utmost limit here). I have always taken those circumstances in te account. For the rest, as far as necessary, the dates of the observations are stated here. With a few exceptions, I myself ascertained the level of the water (with respect to N.A.P., the new water-mark of Amsterdam, as a standard) or it was done under my control; some other results I hold from reliable sources.

In the dunes now, the pression of the deep underground water ascends to about 3 M. above A.P. So on March 30th 1903, in a well of the Harlem waterworks sunk down to 53 M. ÷ A. P., situated in the midst of the dunes, at 3 K. M. west of Sandpoort, and a little further from the polderland, the level of the water was observed to be at 2.91 M. + A. P.; in another well in the dunes, deep 45.5 M. ÷ A. P., almost 2 K. M. further south, and at a distance of $2^1/_2$ K. M. from the polderland, the water ascended to 2.19 M. + A. P. In a third well, close to the water-tower near Overveen and 1 K. M. from the low-lying lands, as deep as 54 M. ÷ A. P., it rose only to 1.20 + A.P. Those three wells are at a distance of $2^1/_2$ to 3 K. M. from the sea. In another well, near to the Brouwerskolkje, sunk down to 70 M. ÷ A.P., (in 1890), at $^3/_4$ K.M. from the one near Overveen and less than $^1/_2$ K.M. from the low-lying land, the water had been seen to ascend to

0.30 M. + A. P. The boring-hole, although still in the dunes, being comparatively low, the water rose here above the ground. The fact that those four wells are situated in the dunes, together with their comparative distances from the lower regions, distinctly make their influence felt here.

Nearer to the inland dunes, the level of the water is everywhere lower than in the middle. On the 11th of April 1903, in the Koningsduin near Castricum, the level of the water in two wells, sunk down to 32 M. ÷ A.P., was 1.195 and 1.23 M. + A.P. They were at a distance of about $^1/_2$ K.M. from each other and they were $^3/_4$ K. M. from the low-lying land; the distance from the sea being $2^1/_2$ K. M. On the same day the level of the water was 0.29 M. + A.P., in a well, deep 33 M. ÷ A.P., near Santpoort, at the inland of the dunes and 2200 M. from the Zuid-Spaarndam polder (the level of the superficial water or the Summer Level here being 2.60 M. ÷ A. P.), whereas it reached no higher level than 0.055 M. + A.P. at Rosenstein, separated from the dunes by the plain of Driehuis, and only 1300 M. from the Noord-Spaarndam polder, (of the same depth as the polder of Zuid-Spaarndam).

Just as in the Brouwerskolkje near Overveen, the water rises above the boring-hole also near Bergen, on the grounds of the Alkmaar waterworks, in wells, only about 20 M. ÷ A. P. deep, for the reason of the dunes having purposely been lowered. Here however, in the midst of high dunes and at $^3/_4$ K. M. from rather shallow polders (summer-level ÷ 1.33M.), it rose to a level of 1.35 M. + A.P., on March 1st 1903.

In a well, deep 40 M.÷ A.P., on the grounds of the paper-manufactory of the firm VAN GELDER & SONS, at Velsen, which well is situated at 1300 M. from the Noord- en Zuidwijkermeer polders (having 2.40 M. ÷ A. P. Summer-Level) the water on April 14th 1903, had a level of 0.26 M. + A. P. without, for 53 hours, there having been any pumping, neither there nor at any of the other wells. Under meteorological conditions which admit of comparison, a well, deep 44 M. ÷ A. P., near the small steam-mill, in the Meerweiden, on the North-Sea Canal, had a level of 0.435 M. ÷ A.P., it being situated only 370 M. from those polders and between two shallower ones (÷ 0.50 and ÷ 1.40 M. Summer-Level). In the Zuidwijkermeerfort, situated in the polder of the same name, a well, 45 M. ÷ A.P. deep, had on March 8th 1902 a level of about 0.80 M. ÷ A. P. Here we distinctly see the lowering of the level of the water in deep wells, from the dunes to the polders, which shows a horizontal motion in that direction.

The same appeared, still more distinctly, south of Harlem, through the influence, which the extensive Haarlemmermeer polder, with its outlying polders, eastward, has on it; the summer level of those polders, which together cover 42000 H. A., being about 5 M. or more under A.P.

At Aerdenhout a well, 32 M. ÷ A.P. deep, showed a level of 0.52 M. + A.P. on May 5th 1903. We may admit that at the time the level of the other wells was being ascertained, it must have been here about 0.40 M. + A.P. This well is 3600 M. from the Haarlemmermeer polder and only 350 M. from the Veenpolder (Summer-Level ÷ 0.75 M.). A well at Heemstede, on Kennemeroord, deep only 26.3 M. ÷ A.P.; but sunk down into the gravelly sand, had on June 2nd 1903 a level of 0.575 M. ÷ A.P. That well, although in the inner-dunes, lies only 2200 M. from the Haarlemmeer polder. Another well, some 100 M. north of the Common-Hall at Heemstede, at about 1300 M. from that polder and still in the inner dunes, had on May 29th, a level of 0.78 M. ÷ A.P. In a third one, nearly 30 M. ÷ A.P. deep, situated within the precincts of the community of Heemstede, but at only 440 M. from the Haarlemmer polder, on Bosbeek, at the border of the inner dunes, and under meteorologic conditions admittting of comparison, the level of the water was 1.29 M.÷ A.P. A well on the Leyden Canal, deep 32 M. ÷ A.P., near the remise of the Harlem Electric Tram, on April 9th 1903, had a level of 0.225 M. ÷ A.P. This well, within the Veenpolder (Summer-Level ÷ 0.75 M.), lies one side at 3700 M. from the encircling canal of the Haarlemmermeer polder, but also at only 1400 M. from the Noordschalkwijk polder, (Summer-Level÷ 1.25 M.) and the other side about 1 K.M. from the dunes. A well near the Harlem Gas Works, in the Veenpolder (÷ 1.40 M. Summer-Level), 1700 M. from the encircling canal of the H.M.P., had, on March 31st 1903, a level of about 1.00 M. ÷ A.P., and in a well on the grounds, reserved for the Harlem Abattoir, the level on April 4th was 1.08 M. ÷ A.P. This well lies in the Roomolen polder (Summer-Level ÷ 1.25 M.), at 1300 M. from the encircling canal of the H. M. P.

On the other hand in a well at Hillegom (behind the building of the Hillegom Bankvereeniging), sunk down to 39 M. ÷ A. P., 1200 from the Haarlemmermeer polder, the level of the water on April 8th 1903 was only 1.20 M. ÷ A.P. Although equally far from that polder as the well near the Common-Hall at Heemstede, the distance that separates this well at Hillegom from the central range of dunes, being 2900 M.; that at Heemstede only 1650 M. The upper-soil moreover at Hillegom is much richer in clay than that at Heemstede, the deep underground water consequently on the first

mentioned spot, being much more under the influence of the pression which makes itself felt in the H. M. polder.

At only 1125 M. north-east of the well at Hillegom, but 300 M. within the Haarlemmermeerpolder, at "Eert-den-Koning", a well has been sunk down to 26.3 M. ÷ A. P., in which on April 21st, (before the heavy rains of the last weeks of that month), the level of the water was 2.57 M. ÷ A. P. The cause of such a difference is some 1500 M. greater proximity of the centre of the Haarlemmermeer polder. In the midst of that polder, at Adolfshoeve, on the east Hoofdweg, 890 M. southwest of the Vijfhuizer Dwarsweg, I saw the water ascend only to 4.70 M. ÷ A. P. in a well, deep 34 M. ÷ A. P., sunk down below a bank of clay, slightly less deep. Probably the rains of a few days before, had raised the water a decimeter above its dry weather level. At Hoofddorp I found on May 8th 1903 a level of 5.03 M. ÷ A.P., in a well only 18.5 M. ÷ A.P. deep. Although less deep than the other wells, also this was sunk into the less fine sand, and near the top of the coarse-grained sand, beneath the less permeable upper-soil of fine sand and clay. If the well had been sunk below the clay-bank and 34 M. ÷ A.P. deep, the water no doubt would have risen a little higher. So the result is, that in the midst of the Haarlemmermeer polder, the underground water, from under the deeper lying clay, can ascend half a metre above Summer Level (this being 5.20 M. ÷ A.P.), on the other hand, from under the clayey top-layer, it can rise but little above it. The pression it acquired in the dunes and in the surrounding, shallower polders, on its way to the H. M. polder, is in the middle of it, at 18.5 M. ÷ A.P., almost entirely lost; and at 34 M. ÷ A.P. reduced to about half a metre, so it can rise but little above the surface underground water, whereas at "Eert-den-Koning", the ascending capacity of the water rising from 26 M. ÷ A.P. is 2.63 M. above Summer Level, or about 1.50 M. above the grass-land of the polder. The upper-soil, we must bear in mind is half permeable, and on its way to the middle of the polder, the water gradually loses more or less its ascending-capacity. Consequently also, the water cannot horizontally move further east, for then it would have to move to parts, where there is more pression.

That indeed the difference in pression between the surrounding higher parts and this deep polder, is the cause of the motion, appeared from observations taken on other spots round the Haarlemmermeer polder, and in the deep polders more east, adjacent to it, including the large Mijdrecht-polder.

North-east of the Haarlemmermeer polder, in the Rieker-polder,

a great many wells have been sunk for military purposes, most of which wells are about 50 M. ÷ A.P. deep. The levels in them were repeatedly sounded by me, which, considering their large number, led to important results. Specially of great significance is what those soundings teach us, as to the direction in which the deep underground water moves. Subjoined table, in which, as much as possible, only wells of corresponding depths have been put down, entirely confirms what I found elsewhere.

Those soundings were done on June 5th 1903. The distances of the wells to the H.M.polder itself, one will get by adding 80 M. to the figure that expresses the distance between them and the encircling canal.

Number of the well.	Depth, in M. ÷ A.P.	Distance in M., to the encircling canal from the H. M. P.	Level of the water in the well, in M. ÷ A.P.
II. 8	56.5	25	3.00
I. 19	47.0	50	2.99
20	49.8	75	2.985
21	45.6	100	2.995
III. 1	47.2	367	2.94
10	55.7	525	2.91
21	51.5	750	2.835
23	52.3	795	2.83
25	52.9	840	2.82
35	55.0	1090	2.81
36	54.0	1120	2.80
37	50.6	1145	2.80
40	52.8	1225	2.78

Here clearly comes out a motion of the deep underground water, from the higher polders, north of the Haarlemmermeer polder, towards this deep polder. On 1200 M. of distance there is an inclination of 0.22 M., or 1,8 : 10000, whereas in other directions, there is no regular inclination. That indeed no general motion from east to west or vice versa is to be thought of, naturally follows from the comparison between the level of the water in wells thus situated. For instance from the following row of wells, all at 25 M. from the encircling canal of the H. M. polder.

Number of well.	Depth in M. ÷ A.P.	Distance in M. from well II. 5.	Level, in M. ÷ A.P.
II. 5	56.3	0	3.025
6	39.0	50	2.98
7	40.1	100	2.98
8	56.5	150	3.00
10	46.5	250	2.99
12	33.5	318	3.005
14	44.0	380	3.025
I. 18	38.0	595	3.01

At the same time the fact stands forth that, once a level reached under the fine-grained and clayey upper-strata, further differences in depths are of little consequence.

Comparison of the other soundings will show forth the same for either statement.

The average level of last mentioned 8 soundings, in wells at 25 M. distance from the encircling canal, is ÷ 3.00 M., so equal to that in well II 8 which we used as starting-point in the first table.

Though there is no great current in the one or the other direction, vertical on the one towards the H. M. polder, (so from east or west,) there seems to exist a slight local motion from the Nieuwe Meer (level about ÷ 0.60 M.) to the west (Summer Level of Rieker polder ÷ 1.80 M.), as may be seen from the comparison between wells, situated at increasing distances from that small lake, but pretty well at an equal distance from the H. M. polder.

Number of well.	Depth, in M. ÷ A.P.	Distance in M., from the N. Meer.	Level, in M. ÷ A.P.
I 1	48.5	60	2.935
2	48.7	90	2.935
3	50.5	110	2.925
4	51.0	135	2.932
7	52.8	220	2.955
8	51.5	235	2.95
9	50.0	235	2.955
10	49.5	235	2.96
12	41.3	300	2.98
II 14	44.0	690	3.025

The real existence of the above indicated motion, from the shallow polders, north of the H. M. polder, towards the latter, is confirmed by observing the level in a well, sunk down to 32.5 M. ÷ A.P. under the direction of Dr. ALEXANDER KLEIN, near the "Huis de Vraag", between the Rieker polder and the Sloter Binnen- and Middelveldsche combined Polders (Summer Level ÷ 2.15 M.), not far behind the Vondel Park. On June 16th 1903, I found the level to be 2.46 M. ÷ A.P. The well lies 3100 M. from the H. M. polder, or about 1800 M. further than well III. 40, in the Rieker polder. So also here there is an inclination of about 1.8 : 10000.

Also towards the polders which lie eastward, adjacent to the H. M. polder, and hydrologically one with it, the motion of the water, deep down, is from the higher to the lower ones. This was shown by soundings, done on June 24th 1903, in wells, all sunk down to about 30 M. ÷ A.P. and belonging to fortifications south-east of Amsterdam. There appeared to be an impelling force in that deep water towards the Groot-Mijdrecht polder (where they keep the water to a Summer Level of ÷ 6.60 M.).

The following small table, concerning observed levels on August 26th 1903, shows this:

	Distance to the Groot-Mijdrecht Polder	Level, in M. ÷ A.P.
Fort near Nigtevecht	7 KM.	1.775
Mil. Post near Oostzijdschen Watermill	5.5 „	2.01
Fort near Abcoude	4.5 „	2.12
„ „ De Winkel	2.5 „	2.29
„ „ Botshol	0.2 „	4.43

The fact that the inclination of the pression-line is specially great here, near the deep polder, and also from Nigtevecht to the Oostzijdschen Watermill, must, I think, be attributed to the greater height to which the gravel-diluvium rises in this part, a thing to which attention has been called, already at the beginning of this paper. The influence of surface-water can therefore make itself felt comparatively strongly, when locally rapid changes occur; at Botshol, on account of the neighbourhood of the deeper polder, and at Nigtevecht on account of the rising of the upper-part of the deposit of coarse grained sand, which at a comparative small distance, east of Nigtevecht, at certain spots, even reaches the surface. The reason being that the artesian regularity of pression, to which the deep

underground water is submitted, is broken by those local irregularities of the geological structure.

That we have not to think of strong currents of the deep underground water, in a general direction for all, but of currents, dependent on the local form of the surface, may finally be confirmed by soundings in two wells, sunk also under the direction of Dr. KLEIN, in the Watergraafsmeer polder (Summer Level ÷ 5.50 M.). One of those wells, in the north of that polder, near the Ooster-railway, at 250 M. north-west of the so called Poort, deep about 39.5 M. ÷ A.P., had on June 18th 1903 a level of 3.215 M. ÷ A.P. In another, presumingly 35 M. ÷ A.P. deep, in the south of that polder, near the Omval, the level was 3.125 M. ÷ A.P., on June 23d 1903. The latter lies 5 K.M. almost straight east, from that near the "Huis de Vraag," which in its turn lies 2.3 K.M. east, but a little towards the north, from well III. 40, in the Rieker polder.

Another well, about 25 M. ÷ A.P. deep lies, in the south-west corner of the Bijlmermeer polder (Summer Level ÷ 4.80), at 4 K.M. north-west of the well near the Oostzijdschen Water-mill, 4.8 K.M. south-east of that near the Omval and 11 K.M. from the Bullenwijker and Holendrechter polder (Summer Level ÷3.35 M.). This well had, under the same meteorological conditions, a level of 3.075 M. ÷ A.P. At the well-known boring done by the corps of military engineers, at Diemerbrug, near the Weesp turnpike, beyond the northern extremity of the Bijlmermeer polder, the level of the water in the well, then 73 M. ÷ A.P. deep, was 2.51 ÷ A.P. on Oct. 18th 1888. That well was 2 K.M. from the eastern border of the Watergraafsmeer polder.

Consequently the result of the different observations is, that there is not a general, so called "artesian" current from east to west or vice versa, in the region between Amsterdam and the H. M. polder, neither south-east of Amsterdam; those found, are but special currents originating in local differences of height of the surface and directed towards the Haarlemmermeer- and adjacent other deep polders and towards the Watergraafsmeer-, the Bijlmermeer- and the Holendrechter polders.

Another result is the conclusion we may draw, as to the direction of the vertical motion of the underground water, by comparing the different levels of the water in the deep wells with that of the varying levels of the underground water rising from smaller depths and with the highest level this reaches. In short in the shallow polders, in the dunes and in the area between them, the direction appears to be downward; in the deep polders, on the other hand,

such as the Haarlemmermeer polder and the adjacent deep ones, upward. It is a wellknown fact that the water in deep wells rises above the surface of the underground water and above the grassland of the deep polders. In polders of smaller depth, the deep wellwater remains below the surface. Likewise the ascending power of the water, as a rule, gradually diminishes towards the middle of the deep polders. In higher parts, such as in the dunes and in the flat sandy adjacent area, the surface of the underground water is considerably higher than the level of the water in the deep wells. So here we find increase of pression from below upward, and descending movement of the water. In the dunes near Castricum the level of the surface of the underground water is about 1.30 M. higher than that reached in the deep wells; at Santpoort, at the inland side of the dunes, the difference even being 1.80 M.

In connection with the above indicated conditions, especially in the colder seasons, when the underground water is generally fed with the water penetrating the soil from the rainfall, the dunes, the shallow polders and the intermediate area will get a fresh supply of water, whereas there is always a loss by the pumping in the deep polders, to which, certainly in no less degree than to the sea, there is a constant affluence. The underground water not being of distant origin, it can as a matter of course be derived only from rains on the spot itself, or at a small distance.

Just a passing remark in connection with the results arrived at, to call the attention to the drying out of the dunes and especially of the lower stretches of land west of the H. M. polder. This drying out, i.e. considerable lowering of the surface-level of the underground water, actually noticed for already half a century, has repeatedly been attributed to the waterworks in the dunes for the water-provision of Amsterdam; to my opinion however it is in the first place due to the draining of the Haarlemmermeer, just half a century ago, from which event dates the powerful subterranean current from the dunes to the deep extensive Haarlemmermeer polder. Especially in the lower tracts from Zuidschalkwijk to Bennebroek, up to a few kilometers from that polder, the drying out process has made itself felt, on account of clay above the coarse-grained sand being almost entirely lacking. In those parts the water in the ditches, when there is no fresh artificial in-flow, will soon sink down, actually making its way under the encircling canal of the H. M. polder, as is proved by the considerably lower level in part of

that region [1]). Ever since, a few years ago, the level of the H. M. polder was lowered 0.30 M., the level of the water in a pond, 4 M. higher, at Meer-en-Berg, and 400 M. outside the polder, was observed to be lowered as much. From this we can imagine how powerful the influence of a lower level of 5 M. must have been at the time when the Lake of Harlem was being drained dry.

As to the motion of the deep underground water, at the side of the dunes, facing the sea, I have been able to make only a few observations. The great uniformity with which the dunes border on the sea however, in connection with the other results of my investigation, permit drawing pretty safe conclusions from them, as to the general condition.

A well known fact is that the superficial water flows from the dunes towards the sea, just as it does inland from the dunes to the adjacent flat area and the polders. A remarkable proof of the water flowing from the dunes to the sea, is the welling up, at ebb-tide, of fresh water on the beach, north of Noordwijk-aan-Zee. Puddles and furrows form themselves, from which, as long as it is ebb, not unlike rills, fed from sources, large quantities of water, only partly consisting of salt-water, flow towards the sea. Particles of clay brought up with the water and found in the ripple-marks on the beach, suggest the presence of a clay-bed, close to the surface, through interruptions of which the welling up of the water takes place. On March 27th 1903, at 11 a.m., it being low-tide, about 9 hours after high-tide, (the wind S.S.E.), I scooped opposite strand-pole N°. 78, from such a rill, about 200 M. long, (the debit of which might be calculated to be in the least 7 M^3 an hour), a sample of water, which proved to contain 11550 mG. of chlorine the Liter. So for $^1/_3$ it was fresh- and for $^2/_3$ sea-water, and hourly more than 2.3 M^3 fresh water found its way into the sea, through that little ebb-rill. The great uniformity now with which the dunes slope down to become beach permit us to accept as a general though in most cases invisible fact what here, through local circumstances, happens visibly.

Another proof for the considerable flowing down of fresh surface-water towards the sea, furnished to me a stone-well at the foot of the dunes, on the beach at Zandvoort, from which the fishing-smacks take their water-store. The bottom of that well is 0.72 M. ÷ A.P.,

[1]) That also from the encircling canal itself, which is about 3 M. ÷ A.P. deep, the water is sinking down, is proved by the fact, that near the Cruquius, the level is always some centimeters lower than in the Spaarne and in the canals of Harlem.

i. e. 0.04 M. above average low-tide mark, and 1.60 M. below high-tide mark. On Febr. 18th 1903, at 4.20 p.m., it being low-tide, the quantity of chlorine of the water in that well, was 291 m.G. the Liter. On March 6th 1903, at 10.30 a.m., about three hours after high-tide, the level of the water in that well was 0.93 M. + A.P. or 0.76 M. above the sea, at that moment.

Also in the deeper, coarse-grained sand-layers, there is a main current of fresh water towards the sea. In a well in the dunes, 350 M. from the sea (low-water line), on the Kerkplein at Zandvoort, sunk down to 28.3 M. ÷ A.P., the level of the water on the 14th of April 1903 was as follows:

At 4.30 p.m.	1.445	M. + A.P.
„ 5 „ „	1.497	
„ 5.25 „ „	1.520	

So a distinct influence of the high-tide, which at IJmuiden rea che its highest level, 1.43 M.+A.P., at 4.55 p.m.; at Zandvoort presumably 8 minutes earlier, is evident.

The next day, in the same well — the deeper one of the two — the level of the water was found to be:

At 12 o'clock	1.28	M. + A. P.
„ 12.35 p.m.	1.24	
„ 1. 5 „ „	1.22	
„ 1.35 „ „	1.195	
„ 2. 5 „ „	1.19	
„ 2.35 „ „	1.193	
„ 3. 5 „ „	1.205	
„ 3.25 „ „	1.20	

Comparing the above figures with those of the self-registering tide-gauge at IJmuiden, it appeared that the influence of the tide makes itself felt 40 minutes later in that well, situated 350 M. from the sea. The sudden way in which the gradual rising of the water stopped at 3.5 p. m. was found to correspond with the somewhat earlier, change in the level of the sea, the difference in time corresponding.

At IJmuiden, 1.30 p.m., the low-tide level was observed to be 0.76 M. ÷ A.P.. So the water in the well was 1.95 M. higher. At high-tide however, it was at that time, but about 0.10 M. above the level of the sea. So the amplitude of the tide influence in the well,

was then about 0.34 M. But the tide rose then unusually high (0.55 M. above the average high-tide mark) the low-tide mark being then just the average one. I think I may estimate the average vertical amplitude in the well to be, at the most, 0.30 M., and believe pretty near to hit it, when accepting 1.30 M. + A.P. as the average level in that well, or 1.50 M. above the average sea-level.

When considering the motion of the deep ground-water, in the direction of the sea, caused by the hydraulic pression in the dunes, we must not overlook the much greater specific weight of sea-water. A column of sea-water 30 M. deep, (with a specific weight of 1.0244, on the average, as that of the North-sea-water), will be kept in balance by a column of fresh water, about 0.75 M. higher. No doubt however the depth of the fresh water, in the coarse-grained sand below it, is much greater than 30 M. ÷ A.P., without any considerable decrease in the ascending power. A direct proof of this is the small percentage of chlorine of the water in the deep well in the Kerkplein, amounting only to 45 m.G. p. Liter, and that in the well on the beach, 30 M. deep, about 250 M. more south, was 52 m.G. the Liter. In statistic equilibrium, 1.50 M. above the average-level of the fresh underground water would correspond with a depth of 61.5 M. But on account of the motion of the fresh water we have here to deal with a condition of dynamic equilibrium; the pressure at great depths consequently is not simply settled by the height, to which the water ascends higher up, in the ground. However below 30 M. (in the coarse-grained sand) there will be little difference, so we cannot but accept, that an extra-pression of 1.50 M. of the sweet groundwater, apparent from the level the water reached in the tube, will correspond with a depth of about 60 M. ÷ A.P.; taking in consideration the decrease of pression downward, we may safely state the depth to be 50 à 60 M. ÷ A.P. One thing is sure, the water which rises from about 30 M. ÷ A.P., has still ascending power above the level of the sea. This may be distinctly observed in the well, sunk on the beach, although being 300 M. nearer to the low-tide line, a considerable decrease can be noticed. At that small distance, the deep underground water in the dunes has already, for the greater part, lost its ascending power and we may accept that not far out into the sea, it is entirely gone. That strong pression-fall must be principally attributed to tide-fluctuation, which every time renews a fourth of the water in the sand, as far as that fluctuation makes itself felt; apparently (the well in the Kerkplein shows it) at a rather considerable distance, from the sea. But also the fact that the beach slopes down — at Zandvoort the depth of the sea, 400 M.

from the low-tide line, being 2.5 M.; 1200 M. beyond that line, 5 M. below A.P. — and that the fine-grained sand intermixed with clay of the original upperlayers for a great part will have been replaced by coarser sea-sand, must considerably have contributed towards greatly increasing the pression-fall of the deep underground water, at the sea-side. At high-tide the flowing off however is very small, and all things considered, the flowing off of the water from the dunes, at the polderland side, certainly will not be less considerable than that towards the sea.

But let us drop this subject, too few facts being at our disposal to judge of that complicated process, and watch the influence of the sea-water at a greater distance from the coast. There can exist no doubt as to the underground of our low-lands being soaked with sea-water. In none of the borings executed in the last scores of years, if only deep enough carried through, the proof of it was lacking; more or less deep, according to circumstances, but the underground water showing an ever increasing quantity of salt, highly exceeding that of all polders ditches or canals, exceeding even that of the Zuiderzee. In or near the dunes, one must go much deeper to find sea-water, than in the polders; and in the polders, on higher ground, as a rule, deeper than in those lower situated. In the Brouwerskolkje, at a depth of 72 M. ÷ A.P., the percentage of chlorine did not exceed that of surface dune-water, neither was this the case in wells of the Harlem water-works, deep 54 M. ÷ A.P.; nor in the one, in the dunes at Elswout, 80 M. ÷ A.P. deep; nor in the Rieker polder at more than 50 M. ÷ A.P. Near the Huis-de-Vraag, in the north-east corner of the Rieker polder, down to 32.5 M. ÷ A.P. only 34 m.G. chlorine a Liter was found; at 46.5 M. ÷ A.P. not more than 81 m.G.; and near "Het Kalfje", on the Amstel, south of Amsterdam, at 31 M. ÷ A.P., only 47 m.G. a Liter. At Purmerend, situated in shallow polders, with Summer Levels of 1.25 to 1.60 M. ÷ A.P., but surrounded by the deep Purmer- (Summer-Level ÷ 4.47 M.), the Beemster- (S.L. ÷ 4.00 M.) and the Wijdewormer polder (S.L. ÷ 4.50 M.), the water rising from 50 M. ÷ A.P., has a quantity of only 43 m.G. of chlorine a Liter. The well-water at Schermerhorn, in shallow polders, between the deep Beemster- and Schermer polders, at 76 M. ÷ A.P. deep, contains 170 m.G. chlorine a Liter. Although the underground water in those deep polders, on the whole is brackish, the quantity of chlorine was only 192 m.G. a L. in the Purmer polder, at about 1 K.M. from the encircling dike, in the direction of Purmerend on the Westerweg, and 600 M. north the church. Similar fresh deep underground

water is also found in the south-east corner of the Beemster polder, opposite Purmerend.

On the whole west of the Haarlemmermeer polder, in wells not greatly exceeding 30 M. in depth, the underground water is equally fresh as dune-water, also at Heemstede and at Hillegom and in some of the shallow polders near Haarlem. At great depth, there is in those parts a considerable increase in the quantity of chlorine. Near the railwaystation of Vogelenzang, between the Leidsche vaart and the rail-road, at 1600 M. from the Haarlemmermeer polder, at a depth of 88 M.÷ A.P., it amounted to 184.6 m.G. a Liter, it being only 35.5 m.G. a Liter at 25 M. ÷ A.P. Near the villa Bennebroek, 650 M. from the Haarlemmermeer polder, 47 M.÷ A.P. deep, it contained 99.4 m.G., and at a depth of 89 M., 245 m.G. chlorine a Liter; on Bosbeek, in the parish of Heemstede, being only 440 M. from that polder, at about 30 M. ÷ A.P., 58 m.G. a L. Numerous instances may be brought forward of the quantity of salt in the underground water growing with its greater depth, and at a higher level, as one draws nearer to the deep polders. A well-known fact is, that in consequence of the flowing down of the underground water from off the dunes, the water of the neighbouring low-lands, up to quite a few kilometers' distance, may be fresh. More considerable and noticeable at greater distance however, is that down-flow deep in the ground. Close to the steam-mill for the draining of the land, in the Meerweiden near Velsen, at full $^1/_2$ K.M. from the dunes, the underground water, 28 M. below A.P., contained 30.5 m.G. chlorine and at 44 M. below A.P., 65.4 m.G.; and even 1 K.M. more east, within the precincts of the fort, in the western corner of the Zuidwijkermeer polder (S.L. ÷ 2.40 M.), at 34 M. ÷ A.P., only 60 m.G.; at 45 M. ÷ A.P., on the other hand, 603 m.G. chlorine a Liter. In the midst of the dunes themselves the ground-water seems to get brackish only at about 150 M. below A.P.

Of special significance is the fact, already stated above, that the underground water in the deep polders is growing salter at a much higher level. So at Eert-den-Koning, only 300 M. within the Haarlemmermeer polder, at 26 M.÷ A.P., the underground water had 367m G. chlorine a Liter. Similar conditions are generally prevailing there. That, generally speaking, the higher percentage of salt cannot be attributed to water from the canals ("boezemwater"), so cannot have got in from the surface, may in the first place, be proved from the fact, that the water in shallow polders, in many places, down to considerable depths is as perfectly sweet as that in the dunes, although one can prove that there is no communication with the dunes; in the second

place, that within those polders just as outside them, but already at a higher level, the water deeper down will be found to have a higher salt standard. At Hoofddorp the quantity of chlorine, at 18.5 M. ÷ A.P., was 202 m.G. a Liter; at 28 M. ÷ A.P., 260 m.G. and at 38 M. ÷ A.P., 993 m.G. With such a rapid increase as in the last 10 M., unmixed sea-water may be expected, at little greater depth.

No doubt can be entertained as to underground sea-water and fresh water in our sea-provinces balancing each other in a way, as indicated by BADON GHYBEN and HERZBERG [1]), very much however modified, in general and in special cases, by the general geological structure with its local modifications. There is no ground for fear of the sea-water coming up from below, in part of the dunes, in which the underground water has been lowered down to the sea-level; the very fact that there are polders, which already for centuries lie below it, and still have fresh water, down to great depths, and that even of the deepest polders the upper-soil, several scores of metres deep, is much more soaked with fresh than with salt water, refutes that fear.

Remarkable however is that at Hoofddorp, although situated in the midst of the Haarlemmermeer polder, the deep underground water is less salt than at Eert-den-Koning, near the edge of the polder, and less still so than some kilometres north-west of Hoofddorp, e. g. on the farm Mentz, where a deep well, presumably equally deep, has water containing 653 m.G. chlorine a Liter, i. e. 2½ times the quantity of that at Hoofddorp. Differences in the condition of the sub-soil are evidently the cause of those differences in the salt quantity.

In the shallow polders, on account of the direction downward of the vertical motion, also the water from the canals ("boezemwater") may be the cause of rendering the deep underground water salt, when locally the structure of the soil does not prevent it.

Bearing in mind, for the motion of the underground water, the significance of the different heights of the polders, and not forgetting the irregularities in the extent, the thickness and the comparative pureness of the clayey beds, also irregularities in the vertical distribution of the water and in the composition of it may be explained.

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[1]) W. BADON GHYBEN in: Tijdschrift van het Kon. Instituut van Ingenieurs 1889, p. 21; HERZBERG in: Journal für Gasbeleuchtung und Wasserversorgung. 1901, p. 815 s.q.q. I count myself happy to have pointed out in lectures, conversations and letters this forgotten merit of one of our engineering-officers, in consequence of which remembrance Mr. C. E. P. RIBBIUS and Mr. R. D'ANDRIMONT have, in their publications given due honours to our compatriot.

Intermixing with water, richer in salt, both from above and from below, may consequently be hindered or furthered by it, also the oozing in of fresh water; the different mixtures, as an other consequence, being able to move horizontally in the one or the other direction, or be prevented to move at all, which explains the different levels they reach.

The hypothetic currents can be dispensed with to explain the existence of fresh water, between 35 and 50 M. ÷ A.P., in the old boring at Sloten, so often urged in proof of powerful subterranean water-currents of distant origin. Of the above mentioned wells in the Rieker polder, those, most west, are only 800 M. east of the boring of 1887. The different levels observed in the wells at Sloten can in reality be due only to local motion, in the direction of the shallower polders (with their higher upper-pression) to the deeper polders, where the pression from above is less powerful. The fresh water, everywhere found there at great depths, down to 50 M. ÷ A.P., can find its origin only in those shallow polders themselves. The very position of the old boring at Sloten, at a corner of the shallow Rieker polder, between two deep polders (the H. M. polder and the Middelveldschen Akerpolder (S. L. ÷ 4.20 M.)), explains the irregularities of composition observed there in the vertical distribution of water, and thus it is, with the boring near Diemerbrug, outside the north corner of the deep Bijlmermeer polder (S.L. ÷ 4.20 M.). At about 250 M. ÷ A.P. water of a somewhat lower standard of salt (minimum 1192 m.G. a Liter) was found; no fresh water, as DARAPSKY lately held forth. Considering what influences are at work in the distribution of the water in our soil, one can but see natural phenomena in all those deviations.

Considering the geological condition of the place itself and of its surroundings, the occurrence at Wijk-aan-Zee, both of fresh water down to 31 M. ÷ A.P. (47.8 m.G. chlorine) and of its getting brackish, already at 50 M. ÷ A.P. (351 m.G. chlorine) may be easily explained; also the presence of a layer of fresh water, between the sea-water, in the sub-soil of IJmuiden.

In this discourse on some general features of the movement of the underground water in our lowlands the question remains to be settled, how it is that some shallow polders, of which the canals and the ditches like those of other, deeper polders, are mostly filled with brackish water, can furnish fresh underground water.

In the first place the answer will be that, by no means, all surface waters of the polders are brackish. Even in the H. M. polder, I found, also at dry seasons, in some places fresh surface water

containing only 78, 60, 35.5 mG. of chlorine a Liter. Holes made in the midst of deep-polder meadows often fill with fresh water, even when a long period of absolute dry weather precedes the digging of them; so in the Purmer-polder, near the above mentioned deep well, on May 13th 1903, the water in such a hole, dug about 1.80 M. deep, contained only 72.6 m. G. chlorine a Liter, the adjacent ditch water having 407 m.G. Near Hoofddorp, in the H. M. polder, in the midst of the Slaperdijk, 250 M. southwest of the Hoofdvaart, after weeks of dry weather, in a hole, the Corps of military engineers had dug, down to 0.40 M. below polder-level, water oozed in, which contained not more than 102 m.G. chlorine a Liter, still that dike (the summit of which is about = A.P.) over all its length stretches between two canals 10 à 15 M. wide, only 40 M. apart and always filled with brackish water, 1 or 1.5 M. deep. The water of those canals at that moment contained 511 m.G. of chlorine a Liter. The level of the water that had gathered in the hole, was 0.11 M. higher than that in the canals and at that time they were even considerably higher than they had been the last month. But those are deep polders, in which the vertical motion of the underground water is from below upward. What to think now of the water that penetrates the soil of the shallow polders? The extent of the land, in the polders, generally exceeding that of the water at least 25 times, and the level of the underground water in rainy seasons, being considerably higher than the neighbouring ditch water, consequently the fresh water will filter down, in a far greater proportion than the brackish, the surface of which forming but an insignificant portion of that of the fresh water fallen in the meadows. The water of the canals ("boezemwater") consequently can but little add, in those rainy seasons, to the salt-standard of the underground water. In the dry season, on the other hand, the land drying out, water must be let in; the soil is then absorbing brackish water from the canals. In fact, however, even such shallow polders, as the Rieker polder and those of Purmerend, which possess fresh underground water below the recent more or less impermeable strata, have brackish underground water near the surface, all the year round. Nevertheless, to my opinion, a great number of phenomena point to the supposition of the deep fresh underground water, found in some of our shallow polders, which have brackish underground water near the surface, being due to rainfall on the spot itself, or at a comparative short distance. This question will be the subject of a further communication.

Considering the facts communicated here, in connection with others,

concerning the quantities of water which from the rainfall penetrates the soil, it need not be further demonstrated that in the sub-soil under the dunes, under the adjacent flat elevated area and under some shallow polders, drinkable water is and will not be lacking, in the main land of the provinces North- and South-Holland, superficially judging so little favoured in this respect, and with two fifths of the population of our country. That the velocity with which the deep underground water can move through the coarse-grained sand, is quite sufficient to make it possible to procure it from the sand in large quantities, a great number of facts prove it. I will mention but one, that of the paper-manufactory at Velsen, of which the six wells, encompassing an area of 0.85 H.A., every 24 hours, on the average, furnish at least 2200 M^3 of fresh water or nearly as much as the town of Harlem wants and about a tenth of what Amsterdam consumed during these latter years. And those wells furnish water, which shows no signs as yet of a too slow horizontal motion ere long being likely, by disturbing the natural equilibrium of the underground fresh and salt-water, to convert the pumped fresh into salt-water. On the contrary the water of the oldest well, full six years in use, has grown a little sweeter still.

Physics. — "*Investigation of a source of errors in measurements of magnetic rotations of the plane of polarisation in absorbing solutions.*" By Dr. L. H. SIERTSEMA. (Communication N°. 91 from the Physical Laboratory of Leiden by Prof. H. KAMERLINGH ONNES.)

(Communicated in the meeting of January 30, 1904).

In a great number of measurements of the magnetic rotation of the plane of polarisation it was found, that this rotation assumes very large values in the neighbourhood of an absorption-band. Similar large values were found by me in an investigation on the negative magnetic rotation of potassium ferricyanide [1]) in dilute solutions. These results agree with the new optical theories which yield for the magnetic rotation the dispersion formula: [2])

$$\varrho = \frac{e}{m}\frac{\lambda}{2V}\frac{dn}{d\lambda}$$

since the quantity $\frac{dn}{d\lambda}$ also assumes a large value near a band.

[1]) Arch. Néerl. (2) 5 p. 447; These Proc. 1901/02 p. 339: Comm. Phys. Lab. Leiden N°. 62, 76.

[2]) These Proc. 1902/03 p. 413, Comm. Phys. Lab. N°. 82.