

Eight centuries of groundwater supply in Liège: from coal exploitation to cutting-edge hydrogeology in chalk and limestone aquifers

Annick Anceau & Alain Dassargues

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As early as the 13th century, the first drainage galleries were developed in Liège linked to coal mining works. These galleries, called *areines* in Belgium, had exit points for water flowing out into the Meuse River or the nearest stream in the valley. The water from these gallery networks was directed as drinking water to the public and private fountains of the city. Due to their importance, these *areines*, called *areines franches*, were protected by strict laws to avoid potential physical damages or contaminations. In 1697, after merging two drinking water drainage galleries, Jean Roland built a new gallery to collect groundwater emerging from springs at the boundary between the Cretaceous chalk and marls (*Smectite de Herve*), northwest of Liège. This gallery carried water from the Hesbaye aquifer to the city's mills and fountains. Five more galleries were built after this first one, and they supplied water collected from the Cretaceous chalk to the city. In the 19th century, the drinking water supply fed by the *areines* and the *Société des Fontaines Roland* was insufficient in quantity and quality. In 1855, at the city's request, Gustave Dumont (André Dumont's cousin) studied the feasibility of a new network of water supply galleries in the Cretaceous chalk aquifer of the Hesbaye region. His report was published in 1856 and included the first known potentiometric map in the world! Dumont's report described the best way to increase the city's drinking water supply and to improve the quality of this water. New galleries were built, and the works were completed by 1869. Since then, the Hesbaye aquifer was a permanent research topic driving the 'Liege school of Hydrogeology' at ULiège. These galleries have been extended in several steps, resulting in more than 40 km of catchment galleries in the Hesbaye aquifer, now operated by the *Compagnie Intercommunale Liégeoise des Eaux*. An overview is also given of the most recent research studies applied to this aquifer in the last 35 years.

References for the historical part

- Anonymous, 1891. *Nécrologie et funérailles de Gustave Dumont, ingénieur des mines, officier de l'Ordre de Léopold: 25 avril 1891. Liège: Aug. Bénard.*
- Belgrand, E. 1846. *Etudes hydrologiques dans les granites et terrains jurassiques formant la zone supérieure du bassin de la Seine. Annales des Ponts et Chaussées. Mémoires et documents relatifs à l'art des constructions et au service de l'ingénieur, 2e série, 12, 2e semestre, no. 153: 129–183.*
- Bischof, K.G. 1847. *Lehrbuch der chemischen und physikalischen Geologie. Bonn: Marcus.*
- Bobeck, P., and J.M. Sharp Jr. 2019. Jean-Baptiste Paramelle and 'The Art of Finding Springs'. *Groundwater* 57, no. 5: 819–823.
- Boussinesq, J. 1877. *Essai sur la théorie des eaux courantes. Mémoires présentés par divers savants à l'Académie des Sciences de l'Institut de France* 23: 1–680.
- Brick, G. 2013. "Water flowing uphill is one of the commonest facts of nature": the emergence of a visual language for groundwater geology. *Groundwater* 51, no. 6: 968–972.
- Butler, M.A. 1933. *Irrigation in Persia by kanats. Civil Engineering* 3, no. 2: 69–73.
- CILE. 1995. *Histoire de l'eau alimentaire en région liégeoise : 1913-1995. [Angleur]: Compagnie Intercommunale Liégeoise des Eaux (CILE).*
- Clutterbuck, J.C. 1850. On the periodical alternations, and progressive permanent depression, of the Chalk water level under London. *Proceedings of the Institution of Civil Engineers* 9: 151–155.
- Darcy, H. 1856. *Les fontaines publiques de la ville de Dijon. Paris: V. Dalmont*
- Darton, N.H. 1909. *Geology and underground waters of South Dakota. U.S. Geological Survey Water-Supply Paper* 227.

- Daubrée, A. 1887. *Les eaux souterraines à l'époque actuelle : leur régime, leur température, leur composition au point de vue du rôle qui leur revient dans l'économie de l'écorce terrestre*. Paris: Vve Ch. Dunod.
- Delcambre, B. and J.-L. Pingot. In press. Carte géologique de Wallonie : Alleu – Liège 42/1-2. Scale 1:25,000. Namur: Service Public de Wallonie.
- de Crassier, L.M.J.G. 1827. *Traité des arènes, construites au Pays de Liège, pour l'écoulement et l'épuisement des eaux dans les ouvrages souterrains des exploitations de mines de houille*. Liège: C.A. Bassompierre.
- Delesse, A. 1858. Carte hydrologique de la ville de Paris. Scale 1:6,666. Paris: [s.n.].
- Delesse, A. 1862. Carte hydrologique du département de la Seine. Scale 1:25,000. [S.l.]: [s.n.].
- de Louvrex, G. 1750. *Recueil contenant les edits et reglemens faits pour le Pais de Liege & Comté de Looz, par les évêques & princes, tant en matiere de police que de justice ; les privilèges accordez par les empereurs aux mêmes païs & autres terres dépendantes de l'Eglise de Liege ; les concordats et traites faits avec les puissances voisines, et ceux faits entre l'evêque & prince, & les Etats ou autres membres dudit Pais ; le tout accompagné de notes. Nouvelle édition continuée, augmentée, corrigée & remise en meilleur ordre, avec des notes ulterieures, par Bauduin Hodin. Partie seconde*. Liège: chez Everard Kints, Imprimeur de S.S.E. & de ses états.
- Deming, D. 2002. *Introduction to Hydrogeology*. Boston: McGraw-Hill.
- Detienne, E.G. 1906. Les eaux alimentaires de Liège. *Annales des Travaux publics de Belgique* 4: 3–107.
- de Vries, J.J. 2007. History of Groundwater Hydrology. In *The Handbook of Groundwater Engineering*, 2nd ed., ed. J.W. Delleur. 1.1–1.39. Boca Raton: CRC Press.
- de Vries, J.J. 2013. The development of groundwater hydrology in The Netherlands between the mid-19th century and the late-20th century. In *History of Hydrogeology*, eds. N. Howden and J. Mather, 149–183. Boca Raton: CRC Press. International Contributions to Hydrogeology No. 28.
- Dumont, A., 1851. *Note sur une application de la géologie à la recherche d'eaux souterraines*. *Bulletins de l'Académie royale des Sciences, des Lettres et de Beaux-Arts de Belgique* 18, no. 1: 47–55.
- Dumont G., 1856. *Rapport fait à l'administration communale relatif aux divers projets qui lui ont été présentés pour procurer à la Ville des eaux alimentaires* (in French). *Bulletin administratif de la Ville de Liège*, Liège, N. Redouté (imprimeur), 109 p.
- Dumont, G. 1871. *Des affaissements du sol produits par l'exploitation houillère : mémoire adressé à l'administration communale de Liège*, 2 vol. Liège: De Thier.
- Dupuit, J. 1848. *Etudes théoriques et pratiques sur le mouvement des eaux courantes*. Paris: Carilian-Goeury et V. Dalmont.
- Dupuit, J. 1863. *Etudes théoriques et pratiques sur le mouvement des eaux dans les canaux découverts et à travers les terrains perméables*, 2nd ed. Paris: Dunod.
- Fayn, J. 1864. *André Dumont, sa vie et ses travaux*. Paris: Noblet et Baudry.
- Forchheimer, Ph. 1886. Über die Ergiebigkeit von Brunnen-Anlagen und Sickerschlitzten. *Zeitschrift des Architekten- und Ingenieur-Vereins* 32: 539–564.
- Fourmarier, P. and L. Denoël. 1930. *Géologie et industrie minérale du pays de Liège*. Paris: Librairie polytechnique Ch. Béranger.
- Gaier, C. 1988. *Huit siècles de houilleries liégeoise : histoire des hommes et du charbon à Liège*. Liège: Editions du Perron.
- Gaier, C. 2012. L'accès à l'eau potable à Liège avant le XIXe siècle. In *Liège à la conquête de l'eau : des origines au centenaire de la CILE*, ed. P. Raxhon, 92–99. Liège: Luc Pire Editions.
- Gobert, T. 1910. *Eaux et fontaines publiques à Liège, depuis la naissance de la ville jusqu'à nos jours*. Liège: D. Cormaux.
- Gümbel, C.W. 1875. Anhang I*). *Grundzüge für die Erforschung der geologischen Beschaffenheit des Bodens und Untergrundes vom Stadtgebiet München's*. In I. Bericht über die Verhandlungen und Arbeiten der vom Stadtmagistrate München niedergesetzten Commission für Wasserversorgung, Canalisation und Abfuhr in den Jahren 1874 und 1875, 25–34. München, E. Mühlthaler.
- Jiang, X.W., J. Cherry, and L. Wan 2020. Flowing wells: terminology, history and role in the evolution of groundwater science. *Hydrology and Earth System Sciences* 24, no. 12: 6001–6019.
- King, F.H. 1899. Principles and conditions of the movements of ground water. 19th Annual report of the U.S. Geological Survey, part 2. Washington, DC: Government Printing Office.
- Le Roy, A. 1869. *L'Université de Liège depuis sa fondation : liber memorialis*. Liège: J.-G. Carmanne.
- Loehnert, E.P. 2013. History of hydrogeology in Central Europe, particularly relating to Germany. In *History of Hydrogeology*, eds. N. Howden and J. Mather, 101–116. Boca Raton: CRC Press. International Contributions to Hydrogeology No. 28.
- Lucas, J. 1874. *Horizontal wells, a new application of geological principles to effect the solution of the problem of supplying London with pure water*. London: Edward Stanford.
- Margat, J., D. Pennequin and J.-C. Roux. 2013. *Histoire de l'hydrogéologie française*. Orléans: Comité français d'Hydrogéologie.
- Mather, J.D. 2001. Joseph Lucas and the term "hydrogeology". *Hydrogeology Journal* 9: 413–415.
- Mather, J.D. 2004. 200 years of British hydrogeology – an introduction and overview. In *200 Years of British Hydrogeology*, ed. J.D. Mather, 1–13. London: The Geological Society. Special Publication No. 225.
- Mather, J.D., H.S. Torrens, and K.J. Lucas. 2004. Joseph Lucas (1846–1926) – Victorian polymath and a key figure in the development of British hydrogeology. In *200 Years of British Hydrogeology*, ed. J.D. Mather, 67–88. London: The Geological Society. Special Publication No. 225.
- Meinzer, O.E. 1934. The history and development of ground-water hydrology. *Journal of the Washington Academy of Sciences* 24, no.1: 6–32.
- Muzikar, R. 2013. Hydrogeology in the Czech Republic. In *History of Hydrogeology*, eds. N. Howden and J. Mather, 47–58. Boca Raton: CRC Press. International Contributions to Hydrogeology No. 28.
- Parker Sr, G.G. 1986. Early stage of hydrogeology in the United States. In *Two-Hundred Years of Hydrogeology in the United States*, eds. J.S. Rosenshein, J.E. Moore, S.W. Lohman, and E.B. Chase, 11–43. U.S. Geological Survey, Open-File Report 86-480.
- Pennink, J.M.K. 1904. *De prise d'eau der Amsterdamsche duinwaterleiding*. *Verhandelingen van het tijdschrift van het Koninklijk Instituut van Ingenieurs* 1903-1904. The Hague: 184–238.
- Prinz, E. 1919. *Handbuch der Hydrologie*. Berlin: Verlag von Julius Springer.
- Robaszynski, F., A. Dhondt, and J.W.M. Jagt. 2001. Cretaceous lithostratigraphic units (Belgium). *Geologica Belgica* 4, no. 1-2: 121–134.
- Thiem, A. 1870. Die Ergiebigkeit artesischer Bohrlöcher, Schachtbrunnen und Filtergallerien. *Journal für Gasbeleuchtung und verwandte Beleuchtungsarten sowie für Wasserversorgung* 14: 450–467.
- Thiem, A. 1876. Resultate des Versuchsbrunnen für die Wasserversorgung der Stadt Strassburg. *Journal für Gasbeleuchtung und Wasserversorgung* 19: 707–719.
- Thorez J. and A. Monjoie. 1973. Lithologie et assemblages argileux de la Smectite de Herve et des craies campaniennes et mastrichtiennes dans le Nord-Est de la Belgique. *Annales de la Société géologique de Belgique* 96: 651–670.
- Tolman, C.F. 1937. *Ground Water*. New York: McGraw-Hill Book Co.
- Van den Broeck, E., and A. Rutot. 1887. *Etude géologique et hydrologique des galeries d'eaux alimentaires de la ville de Liège*. *Bulletin de la Société belge de Géologie, de Paléontologie et d'Hydrologie* 1, Mémoires: 242–275.
- Veeren, F.E.L. 1893. *Proeve eener stroomkaart van het grondwater*. *Tijdschrift van het Koninklijk Nederlands Aardrijkskundig Genootschap*, 2e ser. 10: 1–4.

References about recent research on the Hesbaye chalk

- Batlle-Aguilar, J., Orban, Ph., Dassargues, A., Brouyère, S., 2006, Identification of groundwater quality trends in a chalky aquifer threatened by intensive agriculture, in *Quantitative Geology from Multiple Sources: S10 Use of multiple sources in conditioning/calibrating groundwater flow and transport models*, Stauffer Fr. & Dassargues A. (Eds), Proc. of IAMG2006 Int. Assoc. for Mathematical Geology XIth International Congress. S10-15.
- Batlle-Aguilar, J., Orban, Ph., Dassargues, A. and Brouyère, S., 2007, Identification of groundwater quality trends in a chalky aquifer threatened by intensive agriculture, *Hydrogeology Journal*, DOI 10.1007/s10040-007-0204-y, 15, pp. 1615-1627.
- Biver P., Dassargues A., 1993, La simulation du transport des nitrates dans un aquifère crayeux du Crétacé en Belgique: approche expérimentale et numérique, *Hydrogéologie*, n°2, pp.163-170, BRGM France.
- Biver P. and Dassargues A., 1994, Using a numerical model of transport based on a deterministic theory to infer well protection zones in a chalky aquifer, *Computational Methods in Water Resources X*, vol.1, pp. 183-190, Kluwer Academic Publishers.
- Biver P., Hallet V., and Dassargues, A., 1995, Contribution to the simulation of nitrates transport in a double-porosity aquifer, *Proceedings of Solutions'95, XXVI Int. Cong. of IAH*, Edmonton
- Brouyère S., Dassargues A., Therrien R. and Sudicky E., 2000, Modelling of dual porosity media: comparisons of different techniques and evaluation of the impact on plume transport simulations, *Proc. of the ModelCARE '99 Conference*, Zürich, Eds. Stauffer F., Kinzelbach W. Kovar, K and Hoehn E., IAHS Publication n°265, pp. 22-27.
- Brouyère, S. 2001, Etude et modélisation du transport et du piégeage de solutés en milieu variablement saturé, PhD, ULiège.
- Brouyère S. & Dassargues A., 2002, Reliability of transport models calibrated on field tracer experiments: breakthrough curve sensitivity to tracer injection conditions, in *Calibration and Reliability in Groundwater Modelling: A Few Steps Closer to Reality (Proc. of ModelCARE '2002)*, IAHS Publ. n°277, pp. 339-346.
- Brouyère, S., Carabin, G. and Dassargues, A., 2004, Climate change impacts on groundwater reserves: modelled deficits in a chalky aquifer, Geer basin, Belgium, *Hydrogeology Journal*, DOI 10.1007/s10040-003-0293-1, 12(2), pp.123-134.
- Brouyère, S., Dassargues, A. and Hallet V., 2004, Migration of contaminants through the unsaturated zone overlying the Hesbaye chalky aquifer in Belgium: a field investigation, *Journal of Contaminant Hydrology*, 72, pp.135-164.
- Brouyère, S., Carabin, G. and Dassargues, A., 2005, Influence of injection conditions on field tracer experiments, *Ground Water*, 43(3), pp.389-400.
- Dassargues A., Radu J.P., Charlier R., 1988, Finite elements modelling of a large water table aquifer in transient conditions, *Advances in Water Resources*, Volume 11, n° 2, pp. 58-66.
- Dassargues A., Monjoie A., Lambert J. M. et Pierlot A., 1991, Etude régionale par éléments finis d'une nappe libre située dans les craies du Crétacé en Belgique, *Revue des Sciences de l'Eau*, 4, pp. 39-63, Paris.
- Dassargues A., 1993, Transient simulation of water table aquifers using a pressure dependent storage law, *Computational Modelling of Free and Moving Boundary Problems*, Proc. of the Second Int. Conf. on Moving Boundaries, pp. 3-10, Milan.
- Dassargues A., Monjoie A., 1993, Chalk as an aquifer in Belgium. In: Downing, R.A., Price, M. Jones, G.P. (eds.) *The hydrogeology of the chalk of north-west Europe*. Clarendon Press, Oxford. 153-169.
- Dassargues A., Brouyère S. and Derouane J., 1996, From calibration on tracer test data to computation of protection zones: upscaling difficulties in a deterministic modelling framework, in *Calibration and Reliability in Groundwater Modelling*, Proc. of ModelCare'96, K. Kovar & P. Van Der Heijde Eds., Golden, IAHS Publ. n°237, pp. 253-264.
- Dassargues A. & Hallet V., 2000, Modélisation déterministe des écoulements et du transport de contaminants pour la détermination des zones de protection en Belgique, dans: *Milieus poreux et transferts hydriques (Proc. des 24èmes Journées Scientifiques du GFHN à Strasbourg, novembre 1999)*, Bulletin du Groupe Francophone Humidité et Transferts en Milieux Poreux, n°45, pp.132-136.
- Goderniaux, P., Brouyère, S., Fowler, H.J., Blenkinsop, S., Therrien, R. Orban, Ph. and Dassargues, A., 2009, Large scale surface – subsurface hydrological model to assess climate change impacts on groundwater reserves, *Journal of Hydrology*, 373, pp.122-138, doi:10.1016/j.jhydrol.2009.04.017
- Goderniaux, P., 2010, Impact of climate change on groundwater reserves, PhD, ULiège.
- Goderniaux, P., Brouyère, S., Blenkinsop, S., Burton, A., Fowler, H.J., Orban, P. and Dassargues, A., 2011, Modelling climate change impacts on groundwater resources using transient stochastic climatic scenarios, *Water Resources Research*, 47(12), W12516, 17pp, doi: 10.1029/2010WR010082.
- Goderniaux P., Wildemeersch S., Brouyère S., Therrien, R. and Dassargues A., 2015, Uncertainty of climate change impact on groundwater reserves, *Journal of Hydrology*, 528, pp. 108-121.
- Goderniaux P., Orban Ph., Rorive A., Brouyère S. and A. Dassargues. 2021. Study of historical groundwater level changes in two Belgian chalk aquifers in the context of climate change impacts. In *The Chalk Aquifers of Northern Europe*. Farrell, R. P., Massei, N., Foley, A. E., Howlett, P. R. and West, L. J. (eds), Geological Society, London, Special Publications, 517
- Hakoun V., Orban Ph., Dassargues A. and Brouyère S., 2017, Factors controlling spatial and temporal patterns of multiple pesticide compounds in groundwater (Hesbaye chalk aquifer, Belgium), *Environmental Pollution*, 223, pp. 185-199.
- Hallet V., 1999 Etude de la contamination de la nappe de Hesbaye par les nitrates: hydrogéologie, hydrochimie et modélisation mathématique des processus d'écoulement et de transport, PhD, ULiège.
- Hallet V., Nzali T., Rentier C. and Dassargues A., 2000, Location of protection zones along production galleries : an example of methodology (Proc. of TraM'2000 Conference on Tracers and Modelling in Hydrogeology), A. Dassargues Ed., IAHS Publication n° 262, pp. 141-148.
- Hutzemakers, J., Vandelois, G., Orban, Ph., Dassargues, A., Goderniaux, P. and Brouyère, S. 2024. Evaluation and modelling of the impact of drought on groundwater reserves in Wallonia in the context of climate change. EGU2024 Session: HS8.2.1. <https://hdl.handle.net/2268/317549>
- Orban, Ph., Dassargues, A. and Brouyère, S., 2006, Large-scale groundwater flow and transport modelling : Methodology and application to the Geer basin, Belgium, in *Quantitative Geology from Multiple Sources: S10 Use of multiple sources in conditioning/calibrating groundwater flow and transport models*, Stauffer Fr. & Dassargues A. (Eds), Proc. of IAMG2006 Int. Assoc. for Mathematical Geology XIth International Congress. S10-16.
- Orban, P. 2009 Solute transport modelling at the groundwater body scale: Nitrate trends assessment in the Geer basin (Belgium), PhD, ULiège.
- Orban, P., Brouyère, S., Batlle-Aguilar, J., Couturier, J., Goderniaux, P., Leroy, M., Malozewski, P. and Dassargues, A., 2010, Regional transport modelling for nitrate trend assessment and forecasting in a chalk aquifer, *Journal of Contaminant Hydrology*, 118, pp.79-93.