International Journal of Advanced Research in Arts, Science, Engineering & Management (IJARASEM)

| ISSN: 2395-7852 | www.ijarasem.com | Impact Factor: 3.541 |Bimonthly, Peer Reviewed & Referred Journal|

| Volume 4, Issue 5, September 2017 |

Ground Water Evaluation Of Bikaner District Using GIS (Geographical Information System)

DR. DEVESH KUMAR KHANDELWAL

Associate Professor, Govt. Dungar College, Bikaner, Rajasthan, India

ABSTRACT: A geographic information system (GIS) consists of integrated computer hardware and software that store, manage, analyze, edit, output, and visualize geographic data.[1][2] Much of this often happens within a spatial database, however, this is not essential to meet the definition of a GIS.[1] In a broader sense, one may consider such a system also to include human users and support staff, procedures and workflows, the body of knowledge of relevant concepts and methods, and institutional organizations.

The uncounted plural, geographic information systems, also abbreviated GIS, is the most common term for the industry and profession concerned with these systems. It is roughly synonymous with geoinformatics and part of the broader geospatial field, which also includes GPS, remote sensing, etc. Geographic information science, the academic discipline that studies these systems and their underlying geographic principles, may also be abbreviated as GIS, but the unambiguous GIScience is more common.[3] GIScience is often considered a subdiscipline of geography within the branch of technical geography.

Geographic information systems are utilized in multiple technologies, processes, techniques and methods. They are attached to various operations and numerous applications, that relate to: engineering, planning, management, transport/logistics, insurance, telecommunications, and business.[4] For this reason, GIS and location intelligence applications are at the foundation of location-enabled services, which rely on geographic analysis and visualization.

GIS provides the capability to relate previously unrelated information, through the use of location as the "key index variable". Locations and extents that are found in the Earth's spacetime are able to be recorded through the date and time of occurrence, along with x, y, and z coordinates; representing, longitude (x), latitude (y), and elevation (z). All Earth-based, spatial–temporal, location and extent references should be relatable to one another, and ultimately, to a "real" physical location or extent. This key characteristic of GIS has begun to open new avenues of scientific inquiry and studies.

KEYWORDS: GIS, ground water, evaluation, Bikaner, district, geoinformatics, location, spacetime

I.INTRODUCTION

Bikaner district is located in the north-western part of Rajasthan and encompassed between north latitudes 27°11' to 29°03' and east longitudes 71°52' to 74°15' covering geographical area of 30247.90 Sq. kms. It is bounded on the north by Ganganagar District, on the east by Hanumangarh and Churu Districts, on south by Nagaur and Jodhpur Districts and on the west by Jaisalmer District and International border with Pakistan.[1,2] For administration and development, the district is divided into eight sub-divisions i.e. Bikaner,Kolayat,Nokha, Loonkaransar, Khajuwala, Chhattargarh, Pugal and Dungargarh and eight tehsils, i.e., BIkaner, Kolayat, Nokha, Loonkaransar, Khajuwala, Chhattargarh, Poogal and Dungargarh . The developmental activities of the district are being looked after by six Panchayat Samities, i.e. Bikaner, Kolayat, Nokha, Loonkaransar,Khajuwala and Dungargarh. There are 874 villages and 219 Gram panchayats. [3,4]There is one independent SubTehsil Bajju situated in Kolayat tehsil for better administration. The district has one Municipal Council, 219 Gram Panchayats and 874 Villages. As per 20011 Census, the total population of the district is 2363937 out of which 1563553 is rural population and 800384 is urban population. The district experiences arid type of climate in the east to extremely arid in the west. Mean annual rainfall (1991-2010) of the district is 277.55 mm whereas normal rainfall (1901-1971) is lower than average rainfall and placed at 257.8 mm. Almost 90% of the total annual rainfall is received during the southwest monsoon, which enters the district in the first week of July and withdraws in the mid of September. As the district lies in the desert area, extremes of heat in summer and cold in winter are the characteristics of the desert. [5,6]Both day and night temperatures increase gradually and reach their maximum values in April, May and June. The temperature varies from 48 degree in summer to 1 degree in winter. Atmosphere is generally dry except during the monsoon period. The humidity is the highest in August with mean daily relative humidity of 71% in the morning and 52% in the evening. Geomorphologically, the district can broadly be divided into ten units viz. (1) flat aggraded older alluvial plains, (2) sandy undulating aggraded alluvial plains, (3) flat interdunal plains, (4) sandy undulating interdunal

plains, (5) flood plains and aeolian complex, (6) stabilised sand dunes, (7) active sand dunes, (8) gravelly aggraded alluvial plains, (9) eroded rocky surface and (10) saline depressions. The western, south-western, northern and north eastern parts of the district are largely covered with dunes of different types and magnitudes with flat to undulating interdunal plains. The central eastern and southern parts of the district constitute largely flat and undulating aggraded alluvial plains. The general trend of the regional slope in the area is from SSE (275 mamsl) to NNW (152 mamsl). There are only a few small hill outcrops of about 1-2 mheight near Kolayat in the district. The district has no major river system except for a few short intermittent and ephemeral channels near Kolayat. A few natural lakes or depressions are observed near Gajner, Kolayat, Nal and Lunkaransar.[7,8]

The main Rajasthan Canal enters the area somewhere north of village Bhansar and leaves the district in the southern boundary near village Gogliala. The main canal has a number of branches and distributaries like (1) Naushera Branch, (2) Dathar Branch, (3) Birsipur Branch, and (4) Charanwala branch. Besides the main Rajasthan canal command area, there are other command areas of lift canals. The Indira Gandhi NaharPariyoajna receives water from barrage at HariKaPattan in Amritsar district of Punjab through 204 km. The IGNP canal command area is 591000 hectares in the district (Stage-I 179000 hectares and Stage-II 412000 hectares). The soils of Bikaner district are predominantly light textured, weak – structured, sand to sandy loam with the clay content. Arid climate with low rainfall, high temperature and high evaporation losses has resulted in physical and mechanical disintegration of the parent material giving rise to predominance of coarse fraction in the soil. Very little chemical weathering has taken place and the development of soil is mostly indistinct. Soils are generally of desertic type with poor fertility status and very low water retention capacity.[9,10] Soil profile studied during UNDP Project (1971-74) shows that the hydraulic conductivity in the soil profile reaches upto 10.9 cm/hr while the maximum available moisture in the soil profile remains to the extent of 1.13%. In general the soils have good porosity (40%) and good to very good permeability

Practically, the whole of the surface geology in the greater part of the district is concealed under a thick cover of wind blown sand. However, rocks belonging to Palana Series of Eocene age are exposed around Kolayat, Mar and Bikaner. Sporadic outcrops of sandstone belonging to Lathi (Jurassic) and Badhaura Series (Permo-carboniferous) occur in south-western corner of the district. Lathi and Badhaura sandstones are in small area. Palanas or the Quaternaries are directly underlain by rocks belonging to Marwar Super Group.[11,12]

Jodhpur sandstones and shales are encountered at very shallow depth just below the top Quaternaries in an elliptical area with its longer axis in east-west and shorter axis in north-south direction along Bamanwali-Dhirera and Dulmera line. Thickness of Quaternaries is less around Mahajan in the northern part of the district but increases both in the north towards Arjunsar and in south towards Lunkaransar. Again the Jodhpur sandstones are encountered at shallow depths just below the Quaternaries in the southern part of the district. The subsurface regional geological correlation has revealed the presence of a major longitudinal fault (further east of Bikaner District Boundary). It separates the Precambrian basement platform of the eastern upthrown block with the lower Tertiary of the western downthrown block falling in the Bikaner district. Some smaller parallel faults and a few cross faults are also noticed. One such fault passes in the east-west direction north of Nokha with its down throw in the north. Thus, practically whole of the Bikaner area forms a syncline separated from the southern Nagaur uplift.

II.DISCUSSION

The Palana sandstone member of the Palana series is the main aquifer in the district. Other aquifer formations are sandstone and limestone of Nagaur group of rocks. Jodhpur sandstone and Quaternary alluvium also form aquifer whenever they extend in the zone of saturation. Hydrogeological Conditions: The ground water conditions in different formations in the district are described below. Quaternary Aquifer: The unconsolidated Quaternary sediments attain the status of aquifer in the area north of latitude 28°03’ except around Dhirera and Dhulmera, Mechanical analysis of the aquifer material collected during direct rotary drilling reveals the presence of 20% clay content in the aquifer with sorting coefficient varying from 1.3 to 3.34, the average being in the range of 1.5 to 2.5.[13,14] The ground water occurs under water table conditions and the yield varies from 75 lpm to less than 950 lpm. Thickness of alluvium in the exploratory well at Godwala-II is found to be 187m and the yield of well is 947 lpm (Gadwala-II). The drilled depth of this borehole was 418.49 m whereas constructed depth was 187 m. The slim hole at Karmisar has been drilled to the depth of 510.27 m. The main potential area is the Central part, where Quaternaries form potential aquifers as and when they attain saturation. Palana Sandstone Aquifer: Palana sandstone belonging to lower Eocene to Palaeocene age forms the main and potential aquifer in the district. Palana Sandstone is overlain by Quaternary deposits and is underlain by rocks belonging to Nagaur Group of Marwar Super group. It mainly occupies eastern part of the area and extendsupto the south-western boundary of the district i.e. south of Kalasar. The exploratory drilling indicates that Palana sandstone comprises mainly sandstone fine to coarse grained, well sorted white to grey with some times pink tinge, poorly to moderately cemented,

soft and friable. Locally it is more gravelly, poorly sorted and is intercalated with thin clay beds especially in the lower part, close to it's contact with the thick lower members of the Palana series. In accordance with the regional structural pattern, the saturated thickness of Palana sandstone aquifer increases towards north, except in the axial part of the Bikaner syncline around Sital[15,16] where it is greatly reduced to 15 meters only. North of Bikaner, the saturated thickness of Palana sandstone aquifer is about 80 meters. In Gajner, Akasar and Soa, the saturated thickness negligible but it again attains thickness of about 100 m at Kolayat and Baneri. The drilled depth in Palana sandstone varies from 105 mbgl to 505 mbgl. Palana aquifer is found to be under phreatic conditions. Specific capacity of wells ranges from 3.6 to 28.1 m3 /hr/m and transmissivity ranges up to 720 m2 /day, and permeability from 1.65 to 13.5 m/day. The values of transmissivity remain much below 100m2 /day in the axial zone of the Bikaner syncline and relatively high values are expected in the north-eastern part around Bikaner-Sujandesar and around Raneri in the west. Average specific yield of the aquifer is estimated at 7%. Aquifers of Nagaur Group: Only the upper part of Nagaur Group of rocks comprising mainly sandstones has been encountered just below Palana series in most of Kolayat-Bikaner-Sital-Surpura area. Ground water in Nagaur Sandstone occurs under confined conditions mostly. In the explored part its saturated thickness varies from 40 to 310 m. However, Nagaur sandstone aquifer occurs under water table conditions in Nokha area. In this area its saturated thickness varies from a few m to little over 50 m at Nokha. Yield of wells varies from 200 to 750 lpm. Transmissivity is low and ranges from 2.5 to 50 m2 /day. Permeability is correspondingly low. Specific capacity of wells varies from 0.17 to 1.20 m2 / hr/ m.[17,18] The specific yield of Nagaur Sandstone is estimated at 1% only.In the southern most part of the district, the lower members of the Nagaur group comprising limestone - evaporite sequence also form an aquifer of insignificant potential in a localized patch. Aquifers of Jodhpur Group: Jodhpur sandstone is compact, fine to coarse grained, micaceous and purple to reddish brown in colour. In most of the Bikaner area, it lies below the evaporite sequence and it contains saline ground water. Ground water occurs under phreatic conditions in Palana sandstone and Quaternary sediments whereas it occurs mostly under confined conditions in Nagaur sandstone and Jodhpur sandstone in the district. Both in Tertiaries and Quaternaries, perched water bodies are formed by arresting of downward movement of rainfall percolation by shales and clay lenses in the zone of aeration. Depth to water level in such bodies varies from 5 to 30 mbgl, the shallower being in Pipal area and deeper in Lunkaransar Kutuwas area.[19,20]

Central Ground Water Board periodically monitors water levels through National Hydrograph Network Stations (NHNS) stations four times a year i.e. in January, May (Pre monsoon), August and November (Post monsoon). Block-wise details of depth to water level during pre-monsoon, post-monsoon and water level fluctuation between the two periods are given in table 3. Depth to water level in the district ranges from 8.54 to 111.70 m bgl and 7.64 to 116.40 m bgl during pre monsoon and post monsoon, 2011 periods respectively. During Pre-monsoon, shallow water level 8.54 to 38.35 m bgl exists in Bikaner, Kolayat, Lunkaransar and Dungargarh blocks and deep water level from 67.35 to 111.70 m bgl exists in parts of all the blocks. During Post-monsoon, shallow water level 7.64 to 34.13 m bgl exists in Bikaner, Kolayat, Lunkaransar and Dungargarh blocks and deep water level from 67.22 to 116.40 m bgl exists in parts of all the blocks. Depth to water level maps for Pre-monsoon 2011, Post Monsoon 2011 and Seasonal water level fluctuation (Pre & Post monsoon, 2011) of district have been presented in figure 3, 4 & 5 respectively. Seasonal water level fluctuation of pre & post monsoon, 2011 indicates rise in all the blocks except central and western parts of Nokha, western and eastern parts of the Kolayat block, southern part of the Bikaner block and northern part of Lunkaransar block only. The rising water level may be attributed to negligible exploitation of ground water due to salinity problem. Decadal Water Level Trend for Pre monsoon, 2002–2011 and Post monsoon, 2002 - 2011 have been presented in figure 6 & 7 respectively. During Pre-monsoon period, rising trend upto o.25 m/ year has been observed in major part of the district and in the remaining part of the district, falling trend upto 0.25 m/year has been observed. During Post-monsoon period, rising trend upto 0.25 m/year has been observed during the decade (2002-2011) in majority of the district covering northern and central parts. Rising trend in the range of 0.25 to 0.5 m/year has also been observed in localized pockets in Bikaner and Lunkaransar blocks. Declining trend of upto 0.25 m/year has been observed in southern half of the district. Central Ground Water Board and Ground Water Department, Government of Rajasthan have jointly estimated the ground water resources of Bikaner district based on GEC-97 methodology. The same are presented in Table 4 below. Ground Water Resources estimation was carried out for 13602.51 sq. km. of potential zone area out of which 450 sq. km. is under command, 13152.51sq. km. is non-command.[21,22]

The chemical quality of ground water in the district has been studied from the available data of chemical analysis of water samples collected from the National hydrograph network stations located in various parts of the district. The analytical data of ground water samples indicate that the ground water is, in general, alkaline in nature. The ground water of Bikaner district possesses relatively high mineral concentration, which varies considerably laterally and vertically. Generally, the perched water has less salt concentration except in Lunkaransar - Kutuwas area where it is highly brackish with electrical conductivity around 7000 µS/cm at 25°C. Shallow ground water of the dug well zone has electrical conductivity within 3000 µS/cm at 25°C in the area Chattargarh in Lunkaransar block and in the north eastern edge of Nokha block[23,24]. A perusal of the EC map (Fig.8) prepared on the basis of analytical results of water samples

collected in May 2011 indicates that specific conductance varies from 350 µS/ cm (Jaggasar) to 5270 µS/ cm (Gorabdesar) in the district. Chloride indicates almost the similar pattern. The chloride content varies from 57 to 1463 ppm.[25,26]

III.RESULTS

The Nitrate concentration in ground water varies widely. It ranges from Traces to as high as 420 ppm. In northern and western part of the district, the concentration of nitrate is under permissible limit. Ground water of Bikaner district possesses relatively high mineral concentration which varies considerably laterally and vertically. This is due to combination of factors like physical environment, arid climate, dissolution, reduction, base exchange concentration etc. It has been observed that groundwater quality is saline at all levels in the western part of the district, and the fresh water is underlain by saline water in the northeastern part of the district. The ground water quality is good in south central and south eastern parts of the district except in some patches. The water quality data of exploratory bore holes reveal that the specific conductance varies from 650 to 80290 µS/cm at 25°C.[27] The values more than 3000 µS/cm have been reported at Khujuwala (80290 µS/cm.) in the western part of the district; Motigarh (3485 µS/cm) in the central part of the district, Sajrasar (9515 µS/cm), Lunkaransar (11760 µS/cm), Badoniwali (12575 µS/cm), Malasar (35390 µS/cm), Sobhasar (5015 µS/cm), Banjarwali (19190 µS/cm), Goganpura (13800 µS/cm), Jesrasar (3100 µS/cm), Deshnok (5590 µS/cm), Palana (5270 µS/cm) andRaisar (4095 µS/cm) in the northern,central, eastern and south eastern parts of the district; and Govindsar (18980 µS/cm) and Kolayat (7985 µS/cm) in south western part of the district. Chloride content also indicates the similar trend. Nitrate values vary from Traces at Govindsar to 480ppm at Jesrasar. The values of Nitrate more than 45 ppm have been found at Borabas (152 ppm), Raisar (384 ppm), Surpura (134 ppm), Hurlidhar Vyas colony, Bikaner (140 ppm), Civil lines Bikaner (210 ppm). [28]A total of 42 exploratory wells, 9 observation wells, 2 slim holes and 62 piezometers have been constructed in unconsolidated/ semi-consolidated formations. The exploratory drilling data indicate that the depth of drilling of boreholes in unconsolidated / semi-consolidated formation ranges from 110.00 to 530m depth of construction of wells varies from 124 to 405 m. The discharge of wells varies from 60 to 750 lpm having drawdown from 1 to 39.26 m. The transmissivity of formation lies between 36 and 720 m2 /day. The environmental impact due to development of water resources encompasses the socio-cultural set up created by man to adapt to the demands, and challenges of his naturally occurring circumstances. The ecological system, once disturbed, may not be reverted back in most of the cases especially the problems related to ground water pollution. With the introduction of canal system these have been perceptible changes in the ground wager regime in its command area. There has been rise in water levels in tubewells located in the command area in the entire tract of Indira Gandhi Nahar Pariyojana of which district Bikaner is a part. In the Bikaner District rise in water levels along the canal has been observed in the National Hydrograph Stations at Amarpura, CharanwalaChattargarh, Khakhli, Kherbas, Lakhasar etc. There are no water logged areas at present in the Bikaner District. However, the areas around Kharbara, Dantor, Manaksar, Modayat, Charanwala Bhikampur etc. are more prone to water logging. The main hazard in the development of ground water in the district is its salinity. The ground water of Bikaner district possesses relatively high mineral concentration, which varies laterally and vertically. Also such areas suffer from water quality problem and in some of the areas ground water is highly saline. Villages located in such areas have the basic problem of drinking water requirement and the situation becomes very critical in summers and in drought years. Another issue of concern in the district is that most of the potential zones have registered heavy ground water development causing lowering of water table and drying up of large number of shallow wells or reduction in their yields. Heavy decline of water level in the wells located in Tertiary formation and Quaternary alluvium observed during last 15 years.[28,29]

IV.CONCLUSIONS

Though the overall stage of ground water development of district as on 31.03.2009 is 132.48% (excluding saline), out of total of five blocks having fresh ground water, 2 blocks (Lunkaransar and Kolayat) fall under safe category. Ground water development in these blocks needs to be promoted. Irrigation wells are required to be constructed where groundwater levels are shallow and ground water is suitable for irrigation. Precious Groundwater resources have to be conserved for sustainable availability. Artificial recharge measures are to be employed for augmenting ground water resources by roof top rain water harvesting, construction of sub surface barriers and anicuts at suitable locations. Inferior quality water can be blended with fresh water for irrigation use. Three number of Roof top rain water harvesting structures have been constructed under Demonstrative Artificial Recharge Projects in Bikaner city which were financially aided by CGWB. Watershed Development & Soil Conservation Department has constructed permanent (masonry) check dams under Integrated Watershed Development Project to harvest rainwater, reduce soil erosion and check runoff velocity[26,27]

Recommendations • Awareness program to educate about conservation of precious ground water resources and training on rainwater harvesting will be beneficial to check decline in water level and justified use. • Ground water development in over-exploited, critical and semi-critical area should not be encouraged. • Use of water saving devices like sprinklers, close field distribution channels etc. should be promoted. • Modern agricultural management techniques have to be adopted for effective and optimum utilization of the water resources. This can be achieved by maintaining irrigation through minimum pumping hours as per minimum requirement of water by the crop and also selecting most suitable cost effective crop pattern. • High water requirement crops to be discouraged. Proper agriculture extension services should be provided to the farmers so that they can go for alternate low water requirement economical crops. • Salt resistant crops can be sown in the area having brackish ground water. • In Kolayat and Lunkaransar blocks, which fall under safe category, further ground water development is suggested. • Traditional rainwater harvesting structures like tankas, roof top rain water storage should be encouraged for meeting day to day requirements which will reduce ground water withdrawal. • Large-scale recharge potentials exist in depleted aquifers. Implementation of artificial recharge in such areas through outside surface water sources like lift canal from IGNP system or floodwater during excess rainy years be promoted. • Conjunctive use of ground water and surface water should be encouraged in canal command areas to prevent further water logging in the CCA. Anti water logging measures have to be adopted in the canal command areas.[28,29]

REFERENCES

1. DeMers, Michael (2009). Fundamentals of Geographic Information Systems (4th ed.). John Wiley & Sons, inc. ISBN 978-0-470-12906-7.
2. ^ Chang, Kang-tsung (2016). Introduction to Geographic Information Systems (9th ed.). McGraw-Hill. p. 1. ISBN 978-1-259-92964-9.
3. ^ Goodchild, Michael F (2010). "Twenty years of progress: GIScience in 2010". Journal of Spatial Information Science (1). doi:10.5311/JOSIS.2010.1.2.
4. ^ Maliene V, Grigonis V, Palevičius V, Griffiths S (2011). "Geographic information system: Old principles with new capabilities". Urban Design International. 16 (1): 1–6. doi:10.1057/udi.2010.25. S2CID 110827951.
5. ^ "The 50th Anniversary of GIS". ESRI. Retrieved 18 April 2013.
6. ^ "Rapport sur la marche et les effets du choléra dans Paris et le département de la Seine. Année 1832". Gallica. Retrieved 10 May 2012.
7. ^ MacHarg, Ian L. (1971). Design with nature. Natural History Press. OCLC 902596436.
8. ^ Broome, Frederick R.; Meixler, David B. (January 1990). "The TIGER Data Base Structure". Cartography and Geographic Information Systems. 17 (1): 39–47. doi:10.1559/152304090784005859. ISSN 1050-9844.
9. ^ Tobler, Waldo (1959). "Automation and Cartography". Geographical Review. 49 (4): 526–534. doi:10.2307/212211. JSTOR 212211. Retrieved 10 March 2014.
10. ^ Fitzgerald, Joseph H. "Map Printing Methods". Archived from the original on 4 June 2007. Retrieved 9 June 2007.
11. ^ "History of GIS | Early History and the Future of GIS – Esri". www.esri.com. Retrieved 2015-05-02.
12. ^ "Roger Tomlinson". UCGIS. 21 February 2014. Archived from the original on 17 December 2015. Retrieved 16 December 2015.
13. ^ "GIS Hall of Fame – Roger Tomlinson". URISA. Archived from the original on 14 July 2007. Retrieved 9 June 2007.
14. ^ Lovison-Golob, Lucia. "Howard T. Fisher". Harvard University. Archived from the original on 13 December 2007. Retrieved 9 June 2007.
15. ^ "Open Source GIS History – OSGeo Wiki Editors". Retrieved 21 March 2009.
16. ^ Xuan, Zhu (2016). GIS for Environmental Applications A practical approach. ISBN 9780415829069. OCLC 1020670155.
17. ^ Fu, P., and J. Sun. 2010. Web GIS: Principles and Applications. ESRI Press. Redlands, CA. ISBN 1-58948-245-X.
18. ^ Bolstad, Paul (2016). GIS Fundamentals: A First Text on Geographic Information Systems (6th ed.). XanEdu. ISBN 978-1-59399-552-2.
19. ^ Ablimit Aji; Hoang Vo; Qiaoling Liu; Fusheng Wang; Joel Saltz; Rubao Lee; Xiaodong Zhang (2013). "Hadoop GIS: a high performance spatial data warehousing system over mapreduce". The 39th International Conference on Very Large Data Bases. Proceedings of the VLDB Endowment International Conference on Very Large Data Bases. Vol. 6, no. 11. pp. 1009–1020. PMC 3814183. PMID 24187650.
20. ^ Longley, Paul A.; Goodchilde, Michael F.; Maguire, David J.; Rhind, David W. (2015). Geographic Information Systems & Science (4th ed.). Wiley.

21. ^ Peng, Zhong-Ren; Tsou, Ming-Hsiang (2003). Internet GIS: Distributed Information Services for the Internet and Wireless Networks. Hoboken, NJ: John Wiley and Sons. ISBN 0-471-35923-8. OCLC 50447645.
22. ^ Moretz, David (2008). "Internet GIS". In Shekhar, Shashi; Xiong, Hui (eds.). Encyclopedia of GIS. New York: Springer. pp. 591–596. doi:10.1007/978-0-387-35973-1_648. ISBN 978-0-387-35973-1. OCLC 233971247.
23. ^ Cowen, David (1988). "GIS versus CAD versus DBMS: What Are the Differences?" (PDF). Photogrammetric Engineering and Remote Sensing. 54 (11): 1551–1555. Archived from the original (PDF) on 24 April 2011. Retrieved 17 September 2010.
24. ^ Marwick, Ben; Hiscock, Peter; Sullivan, Marjorie; Hughes, Philip (July 2016). "Landform boundary effects on Holocene forager landscape use in arid South Australia". Journal of Archaeological Science: Reports. 19: 864–874. doi:10.1016/j.jasrep.2016.07.004. S2CID 134572456.
25. ^ Buławka, Nazarij; Chyla, Julia Maria (2015), "Mobile GIS in Archaeology – Current Possibilities, Future Needs Mobile GIS in Archaeology : Current Possibilities, Future Needs. Position Paper", CAA: Digital Archaeologies, Material Worlds (Past and Present), Tübingen: Tübingen University Press, ISBN 978-3-947-25115-5, S2CID 246410784
26. ^ "Aeryon Announces Version 5 of the Aeryon Scout System | Aeryon Labs Inc". Aeryon.com. 6 July 2011. Retrieved 13 May 2012.
27. ^ Puotinen, Marji (June 2009). "A Primer of GIS: Fundamental Geographic and Cartographic Concepts - By Francis Harvey". Geographical Research. 47 (2): 219–221. doi:10.1111/j.1745-5871.2009.00577.x. ISSN 1745-5863.
28. ^ "Digitizing - GIS Wiki | The GIS Encyclopedia". wiki.gis.com. Retrieved 2015-01-29.
29. ^ "Making maps compatible with GPS". Government of Ireland 1999. Archived from the original on 21 July 2011. Retrieved 15 April 2008.