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地域生态环境保护与城市规划布局中的地下水资源评价——以鄂西岗地董市幅 1∶50 000 水文地质图数据集为例

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摘要：鄂西岗地 1∶50 000 水文地质图数据集是在董市幅实施水文地质测绘、地球物理勘探、遥感地质解译、水文地质钻探、水样品采集测试及地下水位监测与统测等工作基础上完成原始数据采集，综合前期收集资料的整理分析与最新采集数据集成编制而成。原始数据采集主要包括遥感地质解译面积 450 km^2，机 (民) 调查点 226 个，地质调查点 125 个，环境地质调查点 16 个，水文地质钻探孔 12 眼，工程地质钻探孔 8 眼，水样品 (全分析、同位素及有机污染样) 合计采集 80 组，丰、枯水期地下水位统测各 40 点次，以及机 (民) 井监测 12 点位 (一个水文年监测) 等，数据采集严格遵守《水文地质调查规范》（DZ/T 0282−2015）、《水文水井地质钻探规程》（DZ/T 0148−2014）等规范与技术要求组织实施，保证数据的准确可靠。数据集采用 MapGIS 6.7 平台辅助制图，坐标系为 1984 年西安坐标系，投影方式为高斯−克吕格投影 (6 度带)。水文地质图编制是以地下水系统理论为指导，充分展现关键水文地质信息与地下水资源现状条件，为区域地下水资源开发利用远景规划与有效保护提供直接依据，能够促进长江中游生态文明建设与长江中游经济带快速发展。

关键词：地下水；水文地质图；地下水系统理论；数据集；水文地质工程；城市地质；董市幅；枝江市；湖北省

数据服务系统网址：http://dcc.cgs.gov.cn

1　引言

地下水资源作为水资源的一种存在形式，对于人类的生活、生产起着举足轻重的作用，特别是地表水系不发达地区，地下水资源甚至成为唯一供水水源，地下水资源丰富程度也将直接影响着地区经济发展（范鹏飞，1998；党学亚等，2018）。合理准确评价地下

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水资源，是地下水资源有效开发利用的关键条件之一，而地下水资源评价的最基础工作是水文地质图的编制 (张剑锋, 1985; 何剑锋和周金龙, 1989)。精准的水文地质图，真实反映着含水岩组空间结构与边界条件、地下水赋存岩层分布区域与富水等级，反映着地下水补径排运动规律，是地下水开发利用、科学管理的基础地质依据，也是城市发展规划的地学支撑。为满足新时代资源与环境并重发展需求，真实客观反映当前区域水文地质条件，中国地质调查局在重要流域或经济区逐步推进实施了 1∶50 000 水文地质调查填图工作，完成水文地质图编制 (吴爱民等, 2016)，一方面丰富了水文地质调查成果，另一方面为地下水可持续利用与生态环境有效保护提供有力保障。

董市幅 (H49E010015) 水文地质调查工作依托于“长江中游宜昌-荆州和武汉-黄石沿岸段 1∶50 000 环境地质调查”二级项目，是长江中游沿岸重点地区部署水文地质调查图幅之一。图幅地理坐标: 111º30′E ~ 111º45′E, 30 º20′N ~ 30 º30′N，地处鄂西岗地与江汉平原过渡地带，地貌主要以岗地和平原为主。 白垩纪中期以来，区域接收陆源碎屑堆积，受挽近期构造影响，西部不断抬升，东部下降，地势总体呈现由西北向东南倾斜，沉积物也呈现由西向东变厚的特征，决定着图幅含水岩组空间结构以及地下水运动过程，为地下水存储、运移提供空间通道及动力条件。图幅内主要出露第四系 (Q)，以冲洪积-冲积松散砂砾石层为主，古近系龚家冲组 (E_2g) 砾岩夹砂岩局部出露，图幅分布松散岩类孔隙水、碎屑岩类孔隙裂隙水两类地下水。松散岩类孔隙水以大气降雨补给为主，在丰水期长江水位高于地下水位，接受长江水补给，枯水期长江水位下降低于地下水位，地下水向长江排泄，构成地下水、地表水相互补排关系，受地层岩性与结构、地形地貌的影响，地下水运动相对较慢，地下水以重碳酸钙型或重碳酸钙镁型淡水为主，富水性地域差异性较大。碎屑岩类孔隙裂隙水主要接受大气降雨补给，在丘岗区也接受相邻含水层侧向补给，地下水以重碳酸钙型淡水为主。

水文地质调查主要以查清水文地质条件、地下水资源丰富程度为目的，同时开展可开采资源量评价。1∶50 000 董市幅 (H49E010015) 水文地质调查数据集是基于前期 1∶200 000 区域地质、水文地质资料整理分析，结合项目 2017 年调查成果综合研究的基础上集合而成，直观表达了图幅内含水岩组的分布与地下水赋存条件、地下水运动规律，对于科学部署地下水开采方案、有效保护地下水资源与维持生态平衡有着重要指导意义，也为岗地、平原区水文地质数据集的采集与编制提供参考价值。图幅数据集基本情况见表 1。

2 数据采集和处理方法

董市幅 (H49E010015)1∶50 000 水文地质图数据集坚持“以需求为导向、以专业为基础，以发展为目标，谋求人–地和谐持续发展”的原则，支撑服务长江中游经济带规划布局。 按照《水文地质调查规范 (1∶50 000)》(DZ/T 0282−2015) 技术要求与调查内容，实施 1∶50 000 水文地质测绘，辅以遥感地质解译、地球物理勘探、水文地质钻探与地下水位统测监测等工作手段，查明图幅含水系统空间结构与边界条件，地下水补给、径流与排泄方式，探讨地下水相关的环境地质问题及其形成机制，服务于地下水资源开发利用与保护、生态环境保护。数据集采集、处理既满足于需求也遵循地质科学规律，图件编制也严格遵照《水文地质调查图件编制规范 (1∶50 000)(送审稿)》编制图幅内容与表达相关要素。

表 1　数据库 (集) 元数据简表

条目	描述
数据库(集)名称	董市幅1∶50 000水文地质图数据集
数据库(集)作者	何军, 中国地质调查局武汉地质调查中心 肖攀, 中国地质调查局武汉地质调查中心 彭轲, 中国地质调查局武汉地质调查中心 许珂, 中国地质调查局武汉地质调查中心
数据时间范围	2017—2018年
地理区域	宜昌市枝江市
数据格式	MapGIS 6.7矢量格式(*.wt、*.wl、*.wp、*.msi)
数据量	14.0 M
数据服务系统网址	http://dcc.cgs.gov.cn
基金项目	中国地质调查局地质调查项目 “长江中游宜昌-荆州和武汉-黄石沿岸段1∶50 000环境地质调查(编号: DD20160250)”
语种	中文
数据库(集)组成	数据集包括1幅水文地质图, 主要包括主图、水文地质柱状图、5个镶图、2个水文地质剖面图。修饰部分包括图名、接图表、比例尺、中国地质调查局局徽、责任签等

2.1　数据采集

水文地质图数据集主要涵盖地理信息要素、地质信息要素与水文地质信息要素三部分主体内容。地理信息元数据通过购置 1∶50 000 地形图获取水系、居民区、行政地名等元素, 坐标系为 1984 年西安坐标系及 1985 年国家高程基准; 地质信息元数据主要依据 1∶200 000 长阳幅区域地质图 (2000 年 12 月修订版) 及其他相关地质资料收集整理获取地层结构、地质构造等元素, 结合实际野外调查数据补充修正 (无 1∶50 000 董市幅区域地质图资料); 水文地质元数据主要通过野外路线调查、地球物理勘探、水文地质钻探与抽水试验、水样品采集测试等资料获取水文地质参数等元素。

水文地质信息采集过程中, 针对地质条件复杂程度与含水岩组区间分布差异性, 遵循重点地区加密调查, 一般地区放宽调查原则, 调查工作在图幅内布署了 21 条路线, 分 48 段实施, 完成调查点数共计 367 点, 其中地层岩性界线调查 112 点、岩土地层调查 13 点、机 (民) 井调查 226 点、江河湖库岸坡稳定性综合调查 14 点、农业污染源调查 1 点及垃圾场调查 1 点, 完成基础数据集成提取。为查清地下含水岩组结构与目标含水层位置及地下水赋存特征, 部署水文地质钻孔 12 个, 按照《水文水井地质钻探规程》（DZT 0148−2014）完成施工成井并进行抽水试验工作。同时, 为掌握地下水动态变化与流场、地下水质状况, 部署民井监测点 6 个 (监测周期为 1 个水文年), 机井监测点 6 个 (监测周期为 1 个水文年), 地下水位统测点 40 点 (丰水期、枯水期各一次), 采集地下水全分析水样 40 组, 氢氧同位素 20 组及有机污染分析水样 20 组 (表 2), 地下水水样由具有国家认证资质的湖南省地质测试研究院 (国土资源部长沙矿产资源监督检测中心) 测试完成, 化学分析内容见表 3。野外调查、水文地质钻探、样品采集测试分析与地下水监测、统测等工作为含水岩组结构与富水性划分、地下水系统边界划定、地下水流向、地下水质量, 地下水类型确定等提供保障, 为主图以及镶图编制提供基本数据支撑。

表 2 基础数据信息采集表

数据类型	数据子分类	单位	数据量
机(民)井点		个	226
地质调查点	地质界线点	个	112
	岩土调查点	个	13
地下水位监测点	机井监测点	个	6
	民井监测点	个	6
	地下水位统测点	处/点次	40/80
环境地质调查点	江河湖库岸坡稳定性	个	14
	农业污染源点	个	1
	垃圾场调查点	个	1
样品采集	地下水全分析样	个	40
	氢氧同位素样	个	20
	地下水有机污染分析样	个	20
地质钻探	水文地质钻探	眼/进尺	12/1 001.6
	工程地质钻探	眼/进尺	8/402.2

表 3 董市幅地下水化学分析数据表

序号	字符名称	数据类型	数据样例	序号	字符名称	数据类型	数据样例
1	水样批号	字符串	C17407	18	Li	浮点型	0.004 6
2	水样编号	字符串	ZJ21	19	Sr	浮点型	0.58
3	分析编号	字符串	C174070018	20	Zn	浮点型	0.000 89
4	地下水类型	字符串	孔隙潜水	21	Se	浮点型	0.00
5	K^+	浮点型	1.28	22	游离CO_2	浮点型	27.00
6	Na^+	浮点型	49.2	23	溶解性总固体	浮点型	662
7	Ca^{2+}	浮点型	126.0	24	Cu	浮点型	0.001
8	Mg^{2+}	浮点型	44.2	25	Mn	浮点型	0.018
9	NH_4^+	浮点型	0.0	26	HBO_2	浮点型	0.004 2
10	Fe^{2+}	浮点型	0.00	27	Ag	浮点型	0.000 2
11	Fe^{3+}	浮点型	0.015	28	Al^{3+}	浮点型	0.000 4
12	Cl^-	浮点型	0.3	29	总硬度	浮点型	496
13	SO_4^{2-}	浮点型	163.0	30	暂时硬度	浮点型	339
14	HCO_3^-	浮点型	413	31	永久硬度	浮点型	158
15	CO_3^{2-}	浮点型	0.00	32	总碱度	浮点型	339
16	NO_3^-	浮点型	75.6	33	总酸度	浮点型	30.71
17	PO_4^{3-}	浮点型	0.12				

注：元素计量单位$mg \cdot L^{-1}$。

2.2 数据处理方法与分析

2.2.1 数据整理

遵循《水文地质调查规范 (1∶50 000)》(DZ/T 0282–2015)以及数据产品支撑地质云建设要求，地质数据均由纸质表格录入数据库，形成电子表格存储，分类存储便于管

理。图幅数据整理主要分为野外综合调查类、水文地质调查类、地质灾害与环境地质问题调查类、野外综合施工类、野外动态监测类与样品测试类，主要内容包括地层岩性、机（民）井调查、地下水位监测与统测、样品采集、水文地质钻探与抽水试验等，内容涉及统一编号、地理位置、地面高程、水位埋深、现状开采量、地层岩性结构、单井涌水量、渗透系数及水样测试分析结果等一系列调查成果。

2.2.2　数据处理方法与结果

含水岩组空间结构数据处理。充分收集整理以往已有钻孔资料以及项目施工水文地质钻孔、工程地质钻孔数据资料，结合地球物理勘探与遥感地质解译分析数据，综合分析以往区域含水岩层特点，划分出目标含水层与相对隔水层，确定含水层位空间位置与深度范围，编制水文地质柱状图与控制性水文地质剖面图，构建立体水文地质结构图，直观展现水文地质结构框架与含水岩组空间分布。

水文地质参数数据处理。通过钻井抽水试验、民井简易抽水试验资料获取含水岩层渗透系数、单井涌水量等水文地质参数值。一方面用以计算地下水资源量，另一方面评价含水岩层富水等级。为便于综合对比地下含水岩层富水性，单井涌水量需要换算成统一口径、统一降深的换算值（谭世燕, 1991; 王琦, 1998）。单井涌水量以换算成 200 mm 口径、10 m 降深的单井涌水量来统一评价，其中，松散岩类孔隙水划分为水量极丰富（>5 000 m^3/d）、水量丰富（3 000 ~ 5 000 m^3/d）、水量中等（1 000 ~ 3 000 m^3/d）、水量贫乏（300 ~ 1 000 m^3/d）和水量极贫乏（<300 m^3/d）5 个富水等级，碎屑岩孔隙裂隙水划分为水量丰富（300 ~ 1 000 m^3/d）、水量中等（50 ~ 300 m^3/d）2 个富水等级，结合含水岩组空间分布及控制性水点水文地质参数，确定各含水岩组富水等级，据此编制水文地质主图富水性分区，刻画水文地质剖面图富水特征。

地下水样测试分析数据处理。通过样品采集、测试分析，采取舒卡列夫分类方法，编制 EXCEL 计算程序确定全分析样品地下水化学类型，根据样点位置结合地下水系统或含水岩层分布特征，综合地下水运动规律，进行地下水化学类型分区，同时，依据地下水硬度数值大小，将地下水划分为极软水（<75 mg/L）、软水（75 ~ 150 mg/L）、中硬水（150 ~ 300 mg/L）、硬水（300 ~ 450 mg/L）与高硬水（450 ~ 700 mg/L）5 个级别，进行硬度分区。综合地下水类型与硬度分区结果绘制地下水水化学图，作为镶图反映图幅地下水水质。

地下水位统测与监测资料处理。充分运用地下水位统测资料，应用 suffer 8.0 软件绘制第四系浅层孔隙水地下水位等值线并结合实际修正，掌握地下水流向，地下水运动规律，查清地下水补给-径流-排泄过程，辅助地下水系统边界划定，编制地下水位等值线图，以镶图形式表达；地下水监测资料用以反映地下水动态变化规律，以及地下水与地表水、大气降雨的响应关系。

通过上述一系列数据资料整理的集成分析，形成董市幅（H49E010015）1：50 000 水文地质图数据集，编制完成水文地质图（图 1）。

3　数据样本描述

3.1　数据类型、命名及其格式

董市幅（H49E010015）1：50 000 水文地质图数据集由水文地质主图、水文地质柱状图、镶图（包括新近系碎屑岩裂隙孔隙水分布图、区域背景图、立体水文地质结构图、孔隙潜水地下水位等值线图、地下水水化学图）、水文地质剖面图、图例与图饰等 6 部

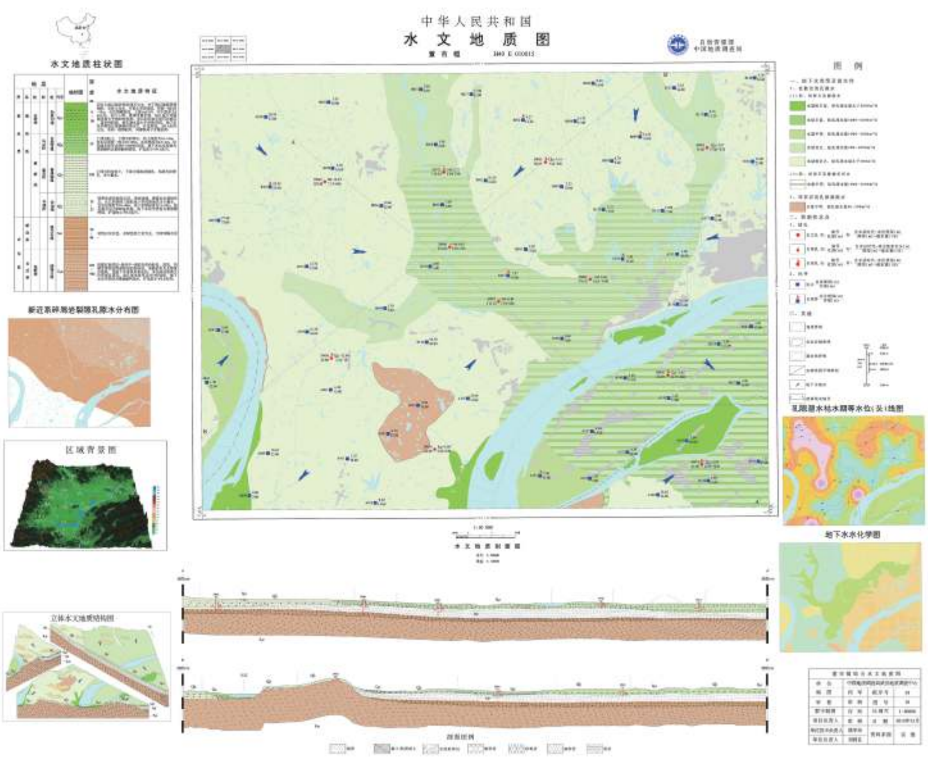

图 1　董市幅 1∶50 000 水文地质图 (简化版)

分组成, 数据以 MapGIS 6.7 文件格式 (*.WP、*.WL、*.WT、*.msi) 存储保存, 并按照不同图层命名与保存文件（陈君, 2000; 庞健锋等, 2017; 吕琳等, 2018）, 各图层划分见表 4。

3.2　坐标系统

水文地质图采用的坐标系为 1984 年西安坐标系及 1985 年国家高程基准, 数据集构建基于 MapGIS 6.7 数据平台, 其空间投影参数如下 (表 5)。

4　数据质量控制和评估

图幅数据集的质量主要取决于两方面因素: 一是采集数据的密度控制与准确程度; 另一方面为编图过程数据的处理及表达准确性。

数据采集严格按照相关规范要求, 符合定额要求完成工作量部署, 满足 1∶50 000 水文地质调查精度。野外调查数据采集实施质量监督, 建立了“项目管理办公室—实施单位—二级项目”和“二级项目—项目任务单元—作业组”2 个三级质量管理体系, 强化原始资料质量检查、验收制度, 各专业工作组实行自检、互检和专检制度, 自检、互检率保证 100%, 专检率为 30%～45%, 检查和整改有记录, 保证原始数据可靠性。水样采集严格按照规范操作要求取样、记录与保存, 做好送样单与送样记录, 测试单位选定具有国家认证资质的测试机构检测, 保证测试结果的可靠性。钻探、地球物理勘探及抽水试验严格按照施工规程与规范操作完成, 数据成果准确可信, 保障了水文地质图数据集成果准确可靠。

图件编制遵循《水文地质调查图件编制规范 (1∶50 000)(送审稿)》, 编图前对数据筛选、分类最后列表统计, 注明名称与资料来源, 认真核对统计资料。数据处理或编图过程中, 对于异常或相互矛盾的数据, 进行仔细多次复核, 查明原因给出合理解释说明, 确保

表 4　董市幅 1∶50 000 水文地质图数据集图层划分

图层类型	图层名称	图层内容	数据格式
主图	含水岩组类型	地下水类型、界线	*.WP、*.WL
	含水岩组富水性	地下水富水程度、界线	*.WP、*.WL
	水系	河流、湖泊及注记	*.WP、*.WL、*.WT
	居民地	房屋、地名	*.WP、*.WL、*.WT
	流向	地下水流动方向	*.WT
	地层构造	地质界线、断层、地层代号	*.WL、*.WT
	交通道路	公路、铁路	*.WL
	图框	图框、比例尺	*.WP、*.WL、*.WT
	剖面部署	剖面线及其注记	*.WL、*.WT
	水文地质点	机井、民井及其注释	*.WT
	图例	水文地质图例	*.WP、*.WL、*.WT
	图饰	责任签、接图表、图名、位置索引图、局徽	*.WP、*.WL、*.WT
镶图	综合水文地质柱状图	柱状图	*.WP、*.WL、*.WT
	区域背景图	地势图	*.msi、*.WL、*.WT
	碎屑岩裂隙孔隙水分布图	新近系碎含水层富水性分区	*.WP
		水系	*.WP
		新近系含水层镶图图名	*.WT
		图例	*.WP、*.WL、*.WT
	孔隙潜水地下水位等值线图	等水位线	*.WL、*.WT
		水位埋深	*.WP
		水系	*.WP
		图例	*.WP、*.WL、*.WT
	地下水水化学图	地下水化学类型划分	*.WP
		总硬度分区	*.WP
		水系	*.WP
		水化学图	*.WL、*.WT
		图例	*.WP、*.WL、*.WT
	立体水文地质结构图	立体图	*.WP、*.WL、*.WT
	水文地质剖面图	剖面图	*.WP、*.WL、*.WT
		图例	*.WL、*.WT

表 5　董市幅 1∶50 000 水文地质图空间投影参数

投影类型	参数
坐标系类型	投影平面直角
椭圆参数	西安80/1975年I.U.G.G推荐椭球
投影类型	高斯-克吕格(横切椭圆柱等角)投影
比例尺分母	50 000
椭球面高程	0 m
坐标单位	mm
投影面高程	0 m
投影中心点经度(DMS)	1 110 000

无误; 编图完成后, 通过图件比对数据, 反复研读, 确保水文地质分区界限、含水岩组富水性与地层岩性对应关系合情合理。通过全面审核、编图过程质量管控, 保证水文地质图内容完整, 数据质量可靠可信, 满足水文地质图规范要求。

5 数据价值

董市幅 (H49E010015)1∶50 000 水文地质图数据集综合反映图幅内含水岩层地下水赋存特征, 地下水运动规律, 表明了地下水补给、径流与排泄过程, 是区域水文地质条件的综合表达。将图幅内地下水富集过程与富水区域直观展现, 能够为当地集中供水应急 (后备) 水源地的选址规划提供直接地学依据, 通过地下水运动规律的准确把握, 也可以为当地工业园区规划部署提供科学指导, 减少地下水污染的发生、发展, 保障地下水生态环境持续健康发展。同时, 通过地下水位等值线图、地下水水化学图等镶图的辅助说明, 也可以为当地地下水开采方案及井深设计提供可靠的依据。总之, 图幅水文地质图数据集能够为地下水资源保护与远期开发利用提供有力依据, 以服务于长江中游经济带社会经济发展、城市规划布局, 推动长江中游生态文明建设与地质环境保护。

6 结论

(1) 董市幅 (H49E010015)1∶50 000 水文地质图数据集主要通过水文地质测绘, 辅以遥感地质解译、地球物理勘探、水文地质钻探与地下水位统测监测等工作手段, 是以查明图幅含水系统空间结构与边界条件、地下水补径排条件及其变化规律, 查清含水岩组分布区域与富水等级为目的, 综合直观展现地下水资源的空间分布特征。

(2) 水文地质图最直接的表达是明确含水层位的富水性, 富水层位的分布及其富水等级, 为地下水开采提供理论支撑。图幅数据集通过含水岩层平面富水性分区, 水文地质剖面图与立体水文地质结构图编制, 直观反映图幅含水岩组空间结构及其富水区域分布、深度范围区间, 可以为科学布署地下水开采方案、有效保护地下水资源提供直接依据支撑。

(3) 数据集以前期工作为基础, 补充开展调查工作, 更新丰富区域水文地质信息, 以地下水系统理论为指导, 突出表达地下水运动规律, 凸显系统性、统一性及时效性特点。水文地质图数据集的表达不仅考虑含水岩层的富水等级, 更充分考虑开采可能产生的地质环境效应, 以保障地下水资源可持续开发利用、生态环境可持续健康发展。

致谢: 董市幅 (H49E010015)1∶50 000 水文地质图数据集是一项系统性、综合性、多样性工作, 需要不同专业的技术人员合作配合完成, 凝聚了项目组全体成员的辛苦劳动与付出, 感谢项目全体成员的不懈努力。感谢湖北省煤炭地质研究院、湖南省地质测试研究院 (国土资源部长沙矿产资源监督检测中心) 技术人员在钻探施工、样品测试工作中的积极配合, 给予数据采集极大的支持。感谢审稿人和编辑部的宝贵意见。

参考文献

陈君. 200. MAPGIS 在数字水文地质图编制中的应用 [J]. 水文地质工程地质, 27(1): 17−20.

党学亚, 曾庆铭, 杨炳超, 顾小凡. 2018. 柴达木盆地 1∶50 000 尕海镇幅水文地质图数据集 [J]. 中国地质, 45(S2): 30−38.

范鹏飞. 1998. 华北平原地下水演化及预测 [J]. 地球学报, 19(4): 346−352.

何剑锋, 周金龙. 1989. 环境水文地质图系编制概览 [J]. 地下水, (2): 73−75.

吕琳, 李伟, 刘元晴, 王新峰, 马雪梅, 邓启军. 2018. 山东省莱芜市幅 1：50 000 水文地质图数据集 [J]. 中国地质, 45(S2): 39−46.

庞健峰, 丁孝忠, 韩坤英, 曾勇, 陈安蜀, 张艳玲, 张庆和, 姚东升. 2017. 1：100 万中华人民共和国数字地质图空间数据库 [J]. 中国地质, 44(S1): 8−18.

谭世燕. 1991. 编制水文地质图中岩层富水性的评价方法问题 [J]. 水文地质工程地质, 18(1): 51−52.

王琦. 1998. 北方岩溶矿床水文地质图编制理论和方法 [J]. 西安矿业学院学报, 18(2): 141−145.

吴爱民, Giovanni Conte, Lucio Martarelli, 马荣. 2016. 意大利水文地质调查编图指南解读及其借鉴意义 [J]. 水文地质工程地质, 43(5): 166−171.

张剑锋. 1985. 水文地质图件编制原则及方法 [J]. 东北水利水电, (8): 36−38.

中华人民共和国国土资源部. 2014. 水文水井地质钻探规程: DZ/T 0148−2014 [S]. 北京: 中国标准出版社.

中华人民共和国国土资源部. 2015. 水文地质调查规范 (1：50000): DZ/T 0282−2015 [S]. 北京: 地质出版社.

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Groundwater Resource Assessment for Regional Eco-environmental Protection and Urban Planning and Layout — A Case Study of the Hydrogeological Dataset of the 1∶50 000 Dongshi Map Sheet in the Downland, Western Hubei

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Abstract: The dataset of the hydrogeological map at a scale of 1∶50 000, of the downland in West Hubei was developed based on the organization and analysis of pre-existing data and the integration of the latest original data obtained from a practical field survey in the Dongshi Map Sheet area, such as hydrogeological mapping, geophysical prospecting, hydrogeological drilling, collecting and testing of water samples and monitoring and simultaneous measurement of groundwater level. The original data involved remote-sensing geological interpretation of an area of 450 km^2, 226 pumping (domestic) wells, 125 points of geological survey, 16 points of environmental geological survey, 12 boreholes of hydrogeological prospecting, 8 boreholes of engineering geological survey, 80 water samples (for total chemical, isotopic and organic pollution analysis), 40 discrete point-times of simultaneous measurement of groundwater levels during the wet and dry seasons and 12 point-locations of pumping (domestic) wells (for monitoring during an entire hydrological year). The original data were acquired in strict accordance with DZ/T 0282–2015 *Specification for Hydrogeological Survey (1∶50 000)*, DZ/T 0148–2014 *The Specification for Hydrogeological Well Drilling* and other technical requirements in order to ensure the accuracy and credibility of the data. The software MapGIS 6.7 was used to prepare the maps in the dataset, adopting the 1984 Xi'an Coordinate System and the Gauss-Kruger projection (6-degree zone). With the theory on groundwater system as a mapping guidance, the hydrogeological map in the dataset can fully reflect the key hydrogeological information and current conditions of groundwater resources, providing a

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direct basis for long-term planning of the development, utilization and effective protection of regional groundwater resources. Therefore, the dataset will promote the ecological civilization construction and repaid development of the economic belt along the middle reaches of the Yangtze River.

Key words: groundwater; hydrogeological map; theory on groundwater system; dataset; hydrogeology engineering; urban geology; Dongshi Map Sheet; Zhijiang city; Hubei

Data service system URL: http://dcc.cgs.gov.cn

1 Introduction

Groundwater resources are a form of water resource that plays a critical role in the everyday life of humankind. In areas with no developed surface water systems, groundwater resources are the only source of water supply, and thus the enrichment of groundwater resources will directly influence the economic development in such areas (Fan PF, 1998; Dang XY et al., 2018). One of the critical conditions for effective development and utilization of groundwater resources is to assess them in a reasonable and accurate manner, whereby the preparation of the hydrogeological maps is mostly fundamental (Zhang JF, 1985; He JF, 1989). Precise and effective hydrogeological maps can really reflect the spatial structure and boundary conditions of water-bearing rock formations and the distribution area and water-yield level of rocks bearing groundwater. Furthermore, the laws of the recharge, runoff and discharge of groundwater can be demonstrated on the maps. Therefore, not only do the hydrogeological maps only provide a basic geological foundation for the development, utilization and scientific management of groundwater but also grant geological support for urban development planning. To meet the demand for both resource development and environmental protection in the modern era and objectively reflect the current regional hydrogeological conditions, the China Geological Survey progressively carried out a hydrogeological survey and mapping on a scale of 1∶50 000 in the critical river basins and economic zones whilst preparing hydrogeological maps along the way (Wu AM, 2016). This enriched the results of the hydrogeological survey and also convincingly guaranteed a sustainable utilization of groundwater and effective protection of the ecological environment.

The Dongshi Map Sheet (H49E010015), with geographical coordinates of E 111°30′–111°45′ and N 30°20′–30°30′, is one of the map sheets that was deployed for the hydrogeological survey in key areas along the middle reaches of the Yangtze River. The hydrogeological survey of the Dongshi Map Sheet was supported by the second-level project titled *Environmental Geological Survey on a Scale of 1∶50 000 in Yichang – Jinzhou and Wuhan – Huangshi Along the Middle Reaches of the Yangtze River*. The map sheet area is located in the transitional zone between the downland in west Hubei and the Jianghan Plain, with downlands and plains constituting the main landform. Terrigenous clastic rocks have been deposited in the map sheet area since the Middle Cretaceous. In late and recent ages, the western part has continued lifting while the eastern part has kept falling, resulting in the general relief that inclines from northwest to southeast and, accordingly, the sediments become thicker from west to east. This determines the spatial structure of the water-bearing rock formations and the motion of groundwater in the map sheet and offers spatial passages and dynamic conditions for the storage and transportation of groundwater. As for the outcrops in the map sheet area, the Quaternary strata of alluvial-diluvial and alluvial loose sand gravels are predominantly exposed. Whereas, conglomerates interbedded with sandstones of Palaeogene Gongjiachong Formation (E_2g) are locally exposed. Two types of groundwater are found in the area (i.e., pore water in loose rocks and pore-fissure water in clastic rocks). The pore water in loose rocks is mainly recharged by atmospheric precipitation. The groundwater of the pore water is recharged by the Yangtze River during wet seasons when its water level of is higher than that of the groundwater, while the groundwater discharges into it during the dry season when its water level is lower than that of the groundwater. In this way, there exists a mutual recharge and discharge between the groundwater and surface water. The groundwater moves relatively slowly subject to stratigraphic lithology and structure, topography and landform. It mainly consists of freshwater of the calcium bicarbonate type or of the calcium and magnesium bicarbonate type. In addition, the water-yield property varies greatly in different regions. The pore-fissure water in clastic rocks is mainly recharged by atmospheric precipitation but can also be recharged laterally from adjacent aquifers in hilly areas. The groundwater of pore-fissure water is primarily freshwater of the calcium bicarbonate type.

The hydrogeological survey principally aims to ascertain the hydrogeological conditions and the enrichment of groundwater resources. Furthermore, recoverable resources are to be assessed in the survey. The 1∶50 000 Dongshi Map Sheet (H49E010015) hydrogeological survey dataset is based on the previous 1∶200 000 regional geological and hydrogeological data collation and analysis, combined with a comprehensive study of the project's 2017 survey results. With this dataset, the distribution of water-bearing rock formations, as well as occurrence conditions and motion rules of the groundwater within the map sheet area, are demonstrated visually. Therefore, the Dataset will provide important guidance on the scientific implementation of groundwater recovery plans, effective protection of groundwater resources and the maintenance of an ecological balance. In addition, it will provide references for the acquisition and preparation of the hydrogeological dataset of downlands and plains. Basic information on the dataset is shown in Table 1.

2 Methods for Data Acquisition and Processing

The Dataset of Hydrogeological Maps of the Dongshi Map Sheet on a Scale of 1∶50 000 is demand-oriented and professional-based, and aims for development and seeks human-land harmony and sustainable development, which will support and serve the planning and layout of the economic belt along the middle reaches of the Yangtze River. During the preparation of the Dataset, the hydrogeological survey and mapping, on a scale of 1∶50 000, were deployed and implemented in accordance with DZ/T 0282–2015 *Specification for Hydrogeological Survey*

Table 1 Metadata Table of Database (Dataset)

Items	Description
Database (dataset) name	Hydrogeological Dataset of the 1∶50 000 Dongshi Map Sheet
Database (dataset) authors	He Jun, Wuhan Center, China Geological Survey Xiao Pan, Wuhan Center, China Geological Survey Peng Ke, Wuhan Center, China Geological Survey Xu Ke, Wuhan Center, China Geological Survey
Data acquisition time	2017－2018
Geographical area	Zhijiang City under Yichang City
Data format	Vector formats of MapGIS 6.7 (*.wt, *.wl, *.wp, *.msi)
Data size	14.0 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	China Geological Survey project titled “Environmental Geological Survey on a Scale of 1∶50 000 in Yichang–Jingzhou and Wuhan–Huangshi in the Middle Reaches of the Yangtze River” (No. DD20160250)
Language	Chinese
Database (dataset) composition	The dataset consists of one hydrogeological map, which mainly includes a master map, hydrogeological histograms, five mosaic maps and two hydrogeological profiles. The other decorations include map name, index map, scale, logo of the China Geological Survey and responsibility signatures.

(1∶50 000). Additionally, geological interpretation of remote sensing images, geophysical prospecting, hydrogeological drilling and simultaneous measurement and monitoring of water levels were also conducted for additional assistance. The spatial structures and boundary conditions of the water-bearing system as well as the methods of groundwater recharge, runoff and discharge in the map sheet area were ascertained. The environmental-geological issues regarding groundwater and their formation mechanism were explored. In this way, the Dataset can serve the development, utilization and protection of groundwater resources as well as eco-environmental protection. The acquisition and processing of the data in the Dataset were demand-oriented according to the laws of geology. The maps in the Dataset including the content and relevant elements to be expressed were prepared in strict accordance with the *Specification for the Compilation of Hydrogeological Maps* (1∶50 000) (the version for approval).

2.1 Data Acquisition

The Dataset mainly covers three parts, i.e., geographical information elements, geological information elements and hydrogeological elements. The metadata of geographical information, consisting of water systems, residential areas and administrative place names were obtained from the 1∶50 000-scale topographical map, with the 1984 Xi’an Coordinate System and the 1985 National Height Datum as the coordinate system. The metadata of geological information, including stratigraphic structures and tectonic information, were obtained by collecting and collating the *Regional Geological Map of the Changyang Map Sheet on a Scale of 1∶200 000* (revised edition in Dec. 2000) and other relevant geological materials. They were supplemented and amended with the data obtained from the field survey (no regional geological maps of the Dongshi Map Sheet, on a scale of the 1∶50 000, are available). The hydrogeological metadata were obtained through a field investigation along pre-determined routes, geophysical prospecting, hydrogeological drilling and pumping tests and the collection and testing of water samples, among others.

During the acquisition of hydrogeological information, the survey was intensified in critical areas and eased in normal areas, targeting the complexity of geological conditions and the disparities in interval distribution of water-bearing rock formations. 21 routes were deployed within the map sheet area. They were divided into 48 segments and then surveyed. 367 points were surveyed in total, including 112 for the lithologic boundary survey of strata, 13 for the survey of rock and soil strata, 226 for the survey of pumping (domestic) wells, 14 for the comprehensive survey of the stability of bank slopes of rivers, lakes and reservoirs, 1 for the survey of agricultural pollution sources and 1 for the survey of lumps. As a result, the basic data were collected. To ascertain the structure of the underground water-bearing rock formations, the locations of target aquifers and the occurrence features of groundwater, 12 hydrogeological boreholes were deployed and drilled in accordance with DZ/T 0148−2014 *The Specification for Hydrogeological Well Drilling*. Then pumping tests were conducted. Meanwhile, to understand the dynamic change, flow field and water quality of the groundwater, 6 monitoring points were deployed in domestic and pumping wells (monitoring cycle: one hydrological year) and 40 points for simultaneous measurement of groundwater levels were deployed (respective once during wet and dry seasons), 40 groundwater samples for chemical analysis, 20 samples for isotope analysis of H and O and 20 samples for analysis of organic pollution (Table 2). These groundwater samples were tested in the nationally-certified Hunan Province Geological Testing Institute (Changsha Mineral Resources Supervision and Inspection Center, Ministry of Land and Resources). The analytical chemical compositions are shown in Table 3 and the analytical results are listed in the dataset. The field survey, hydrogeological drilling, the acquisition, testing and analysis of samples and monitoring and simultaneous measurement of groundwater levels guaranteed the classification of the structure and water-yield property of water-bearing rock formations, the determination of the boundaries of groundwater systems and the determination of the flow direction, water quality and groundwater type. Additionally, they provided basic data for the compilation of the master map and mosaic maps.

2.2 Data Processing and Analysis

2.2.1 Data Collation

In accordance with DZ/T 0282−2015 *Specification for Hydrogeological Survey* (1∶50 000) and the requirement that the data products achieved should support the building of GeoCloud, all geological data in paper data tables were input into the database. As a result, all

Table 2 Acquisition of Basic Data

Data type	Data subtype	Unit	Data quantity
Pumping (domestic) well point		pcs	226
Geological survey point	Geological boundary point	pcs	112
	Survey point of rock and soil strata	pcs	13
Monitoring point of groundwater level	Monitoring point of pumping well	pcs	6
	Monitoring point of domestic well	pcs	6
	Point for simultaneous measurement of groundwater level	location/point-time	40/80
Environmental geological survey point	Stability of bank slopes of rivers, lakes and reservoirs	pcs	14
	Survey point of agricultural pollution source	pcs	1
	Point for dump survey	pcs	1
Groundwater sample	Samples for total chemical analysis	pcs	40
	Samples for isotope analysis of H and O	pcs	20
	Samples for organic pollution analysis	pcs	20
Geological drilling	Hydrogeological drilling	Borehole/footage	12/1 001.6
	Engineering geological drilling	Borehole/footage	8/402.2

the data were stored in spreadsheets by data types. In this way, convenient management is available. The data of the map sheet were collated and divided into six categories (i.e., field comprehensive survey, hydrogeological survey, survey of geological disasters and environmental geological problems, field comprehensive construction, field dynamical monitoring and sample testing), primarily covering stratigraphic lithology, pumping (domestic) well survey, monitoring and simultaneous measurement of groundwater levels, sampling, hydrogeological drilling and pumping tests. Unified numbering was conducted. The survey results including geographical location, surface elevation, burial depth of water level, allowable yield, lithologic structure of strata, single well water yield, permeability coefficient and results of water sample testing and analysis were collated.

2.2.2 Data Processing Methods and Results

Data processing of spatial structures of water-bearing rock formations. Pre-existing borehole data, as well as the data of hydrogeological boreholes and engineering geological boreholes drilled during the project construction, were fully collected and collated. Previous features of aquifers in the map sheet area were comprehensively analyzed. Based on these and the data obtained from geophysical prospecting, geological interpretation and analysis of remote-sensing images; the target aquifers, including their locations and depth scope, and additional relative aquicludes were determined. Furthermore, hydrogeological histograms and

Table 3 The Analytical Chemical Compositions of the Groundwater from Dongshi Map-sheet Area

No.	Character name	Data category	Real example	No.	Character name	Data catagory	Real example
1	Water sample batch No.	String	C17407	18	Li	Floating point	0.004 6
2	Water sample No.	String	ZJ21	19	Sr	Floating point	0.58
3	Analysis No.	String	C174070018	20	Zn	Floating point	0.000 89
4	Groundwater type	String	Pore diving	21	Se	Floating point	0.00
5	K^+	Floating point	1.28	22	Free CO_2	Floating point	27.00
6	Na^+	Floating point	49.2	23	Soluble total solids	Floating point	662
7	Ca^{2+}	Floating point	126.0	24	Cu	Floating point	0.001
8	Mg^{2+}	Floating point	44.2	25	Mn	Floating point	0.018
9	NH^{4+}	Floating point	0.0	26	HBO_2	Floating point	0.004 2
10	Fe^{2+}	Floating point	0.00	27	Ag	Floating point	0.000 2
11	Fe^{3+}	Floating point	0.015	28	Al^{3+}	Floating point	0.000 4
12	Cl^-	Floating point	0.3	29	Total hardness	Floating point	496
13	SO_4^{2-}	Floating point	163.0	30	Contemporary hardness	Floating point	339
14	HCO^{3-}	Floating point	413	31	Permanent hardness	Floating point	158
15	CO_3^{2-}	Floating point	0.00	32	Total alkalinity	Floating point	339
16	NO^{3-}	Floating point	75.6	33	Total acidity	Floating point	30.71
17	PO_4^{3-}	Floating point	0.12				

Note: Elemental measurement unit $mg \cdot L^{-1}$

controlling hydrogeological profiles were compiled and 3D hydrogeological structure maps were constructed. In this way, the framework of the hydrogeological structure and the spatial distribution of water-bearing rock formations in the area were visually presented.

Processing of hydrogeological parameters. Values of hydrogeological parameters, such as permeability coefficient and single well water yield of aquifers, were determined from pumping tests of drilled wells including simple pumping tests of domestic wells. These values were used to calculate groundwater resources and also to assess the water abundance grade of aquifers. Single well water yields need to be converted into values under the same diameter and the same drawdown for ease of comprehensive comparison of the water-yield property of underground aquifers (Tan SY, 1991; Wang Q, 1998). In this Dataset, single well water yields were converted into values corresponding to a diameter of 200 mm and drawdown of 10 m. According to the assessment results, pore water in loose rocks was classified into five grades, in terms of water-yield property, i.e., very rich (>5 000 m^3/d), rich (3 000–5 000 m^3/d), moderate (1 000–3 000 m^3/d), poor (300–1 000 m^3/d) and very poor (<300 m^3/d). Whereas, pore-fissure water in clastic rocks was divided into two grades, i.e., rich (300–1 000 m^3/d) and medium (50–300 m^3/d). Based on this, in addition to the spatial distribution of water-bearing rock formations and hydrogeological parameters of control water points, the grades of water-yield property were determined. Furthermore, the water-yield-property-based zones in the hydrogeological master map were prepared and the water-yield property was also portrayed on hydrogeological profiles.

Data processing of the analysis on the groundwater samples. Groundwater samples were collected, followed by testing and analysis of the samples. The hydrochemical types of the samples for total chemical analysis were determined with an EXCEL computing program that was developed with the Shukarev classification method. The hydrochemical-type-based zones of the groundwater were determined according to locations of the samples, the distribution of groundwater systems or aquifers, along with the motion law of groundwater. Meanwhile, the groundwater was classified into five categories based on their hardness, i.e., very soft water (<75 mg/L), soft water (75–150 mg/L), moderately hard water (150–300 mg/L), hard water (300–450 mg/L) and highly hard water (450–700 mg/L). Accordingly, hardness-based zones were determined. The hydrochemical maps of the groundwater were further prepared based on the types and hardness-based zones of the groundwater. These maps, in mosaic map form, are used to reflect the water quality of the groundwater within the map sheet area.

Data processing of simultaneous measurement and monitoring of groundwater levels. The water level contour lines of the Quaternary shallow pore-water were plotted with the software Surfer 8.0 by fully applying the information on simultaneous measurement of groundwater levels. Then they were modified according to actual conditions. The flow direction and motion rules of the groundwater were understood, the recharge – runoff – discharge process of the groundwater was ascertained and the boundaries of groundwater systems were delineated for supplementary assistance. Based on these, groundwater-level contour maps were compiled and expressed in a mosaic map form. The information on groundwater monitoring is used to reflect the law of dynamic change of the groundwater together with the relation of the groundwater with surface water and atmospheric precipitation.

The Dataset was achieved and the hydrogeological map (Fig. 1) of the Dongshi Map-sheet (H49E010015) on a Scale of 1：50 000 was compiled with a series of data collation, integration and analysis as mentioned above.

3 Description of Data Samples

3.1 Data Types, Names and Their Formats

The Dongshi Map-sheet hydrogeological dataset is composed of the hydrogeological master map, hydrogeological histograms and mosaic maps (including the Neogene clastic-rock pore-fissure water distribution map, regional landform map, 3D hydrogeological structure map, groundwater level contour map of pore water and hydrochemical map of groundwater), the hydrogeological profiles, legends and decorations. The Dataset is stored in the files of MapGIS 6.7 (*.WP, *.WL, *.WT, *.msi). The files are named and saved by different map layers as shown in Table 4 (Chen J, 2000; Pang JF et al., 2017; Lyu L et al.,2018).

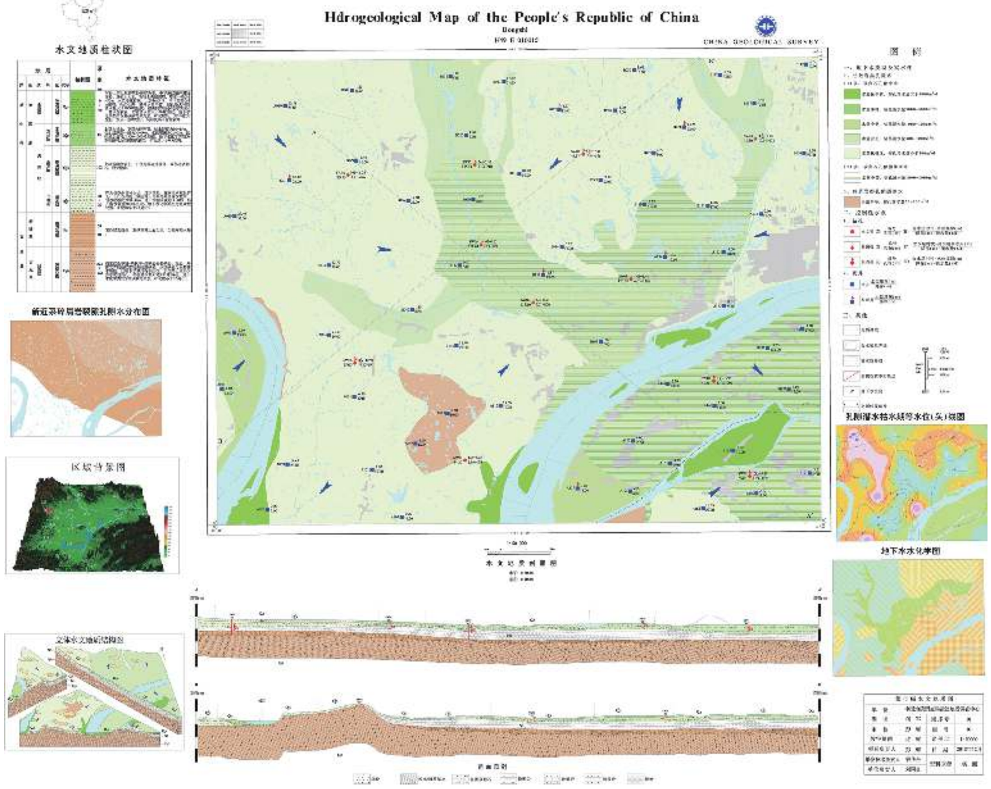

Fig. 1 The hydrogeological map of the Dongshi Map-sheet on a Scale of 1：50 000 (simplified version)

3.2 Coordinate System

The hydrogeological map was prepared in the 1984 Xi'an Coordinate System and 1985 National Elevation Reference, and the Dataset was developed with MapGIS 6.7. The spatial protection parameters are shown below (Table 5).

4 Data Quality Control and Assessment

The quality of the Dataset mainly depends on the density control and accuracy during data acquisition as well as the accuracy of data processing and expression during map preparation.

The data was acquired in strict accordance with applicable specifications; workload was deployed according to quotas and the accuracy of the hydrogeological survey, on a scale of 1：50 000, was satisfied. Quality supervision was implemented for field data acquisition. Two three-level quality management systems were established, i.e., the first one consisting of the project management office, executive entity and secondary-level project and the other comprising of secondary-level project, task unit of the project and the operation team. Quality inspection and acceptance systems were strengthened for original data acquisition. Additionally, self-checks, mutual checks and specific checks were implemented in all professional working teams, with a self-check rate and mutual check rate of 100% and a specific check rate of 30%–45%. Furthermore, the checks and modifications were all recorded accurately. In this manner, it can be ensured that the original data are credible. The

Table 4 Division of Map Layers in the Dataset of Hydrogeological Maps on a Scale of 1：50 000 of Dongshi Map Sheet

Map layer type	Map layer name	Map layer contents	Data format
Master map	Type of water-bearing rock formation	Groundwater types and their boundaries	*.WP, *.WL
	Water-yield property of water-bearing rock formation	Groundwater water-yield property grades and their boundaries	*.WP, *.WL
	Water system	Rivers, lakes and marks	*.WP, *.WL, *.WT
	Residential area	Houses and area names	*.WP, *.WL, *.WT
	Flow direction	Flow direction of groundwater	*.WT
	Stratigraphic structure	Geological boundaries, faults and stratum codes	*.WL, *.WT
	Traffic road	Highways and railways	*.WL
	Map frame	Frames and scales	*.WP, *.WL, *.WT
	Profile deployment	Profile lines and their notes	*.WL, *.WT
	Hydrogeological point	Pumping and domestic wells and their notes	*.WT
	Legend	Hydrogeological legends	*.WP, *.WL, *.WT
	Decoration	Responsibility signatures, index map, map titlesLocation index plan	*.WP, *.WL, *.WT
Mosaic map	Integrated hydrogeological histogram	Histograms	*.WP, *.WL, *.WT
	Regional landform map	Relief map	*.msi*,.WL*,.WT
	Clastic-rock pore-fissure water distribution map	Water-yield-property-based zones of Neogene aquifer of clastic rocks	*.WP
		Water systems	*.WP
		Mosaic map titles of Neogene aquifers	*.WT
		Legends	*.WP, *.WL, *.WT
	Groundwater level contour map of pore water	Water contour	*.WL, *.WT
		Burial depth of water level	*.WP
		Water systems	*.WP
		Legends	*.WP, *.WL, *.WT
	Hydrochemical map of groundwater	Hydrochemical-type-based zones of groundwater	*.WP
		Total hardness-based zones	*.WP
		Water systems	*.WP
		Hydrochemical maps	*.WL, *.WT
		Legends	*.WP, *.WL, *.WT
	3D hydrogeological structure map	3D map	*.WP, *.WL, *.WT
	Hydrogeological profile	Profiles	*.WP, *.WL, *.WT
		Legends	*.WL, *.WT

groundwater samples were taken, recorded and stored strictly in accordance with the applicable codes. Sample presentation forms and records were filled accurately and retained. Furthermore, the groundwater samples were tested in nationally-certified testing entities, ensuring that the

Table 5 Spatial Projection Parameters of the Dataset of Hydrogeological Maps of Dongshi Map Sheet on a Scale of 1∶50 000

Projection type	Parameter
Coordinate system type	Projected rectangular plane coordinate system
Ellipsoid parameters	Xi'an 80 Coordinate System/the ellipsoid parameters recommended by I.U.G.G in 1975
Projection type	Gauss-Kruger (transverse elliptic cylinder equiangular) projection
Scale denominator	50 000
Ellipsoid elevation	0 m
Coordinate Unit	mm
Projection plane elevation	0 m
Longitude of central point of projection (DMS)	1 110 000

testing results are credible. The drilling, geophysical prospecting and pumping tests were all carried out strictly in accordance with the operating procedures and codes, guaranteeing that the results are accurate and credible. Therefore, the results used in the Dataset are accurate and credible.

The maps in the Dataset are compiled in accordance with *Specification for the Compilation of Hydrogeological Maps* (1∶50 000) (the version for approval). Before map preparation, the data are screened, classified and, finally, statistical lists are developed. Meanwhile, the names and sources of the data are marked and then the statistics are carefully checked. During data processing or map compilation, abnormal data or any data conflicts are reviewed repeatedly to discover the causes and thenjustified, and thus to ensure that no errors exist. After map compilation, the data are compared among the maps and studied repeatedly to ensure that hydrogeological zone boundaries, including the relation between the water-yield property and stratigraphic lithology of water-bearing rock formations, are reasonable. Comprehensive reviews and quality controls during map compilation are conducted to ensure that the contents in the hydrogeological maps are complete and that the data quality is reliable and credible, and thus to meet the codes of hydrogeological maps.

5 Value of the Data

The Dataset meticulously reflects the occurrence features and motion laws of the groundwater in aquifers in the map sheet area and demonstrates the groundwater recharge – runoff – discharge process within the area. Therefore, the hydrogeological conditions in the area are comprehensively presented in the Dataset. Intuitive groundwater enrichment process and water-rich zones within the map sheet makes it possible to provide a direct scientific basis for the siting and planning of emergency (backup) water sources for local centralized water supply. Meanwhile, accurate understanding of groundwater motion laws can provide scientific guidance on the planning and deployment of local industrial parks, thus mitigating the occurrence and development of groundwater pollution and guaranteeing a sustainable and healthy development of the ecological environment of the groundwater. Furthermore, supporting details in mosaic maps, such as water level contour maps and hydrochemical maps of groundwater, will provide a reliable foundation for plan preparation and well depth design in terms of local groundwater recovery. Overall, the Dataset will provide a strong basis for the protection and long-term development and utilization of groundwater resources, in order to serve social and economic development and urban planning & layout in the economic belt along the middle reaches of the Yangtze River and to promote the ecological civilization construction and geological environmental protection there.

6 Conclusion

(1) The Dataset was mainly developed by hydrogeological survey and mapping, with the geological interpretation of remote-sensing images, geophysical prospecting, hydrogeological drilling and simultaneous measurement and monitoring of water levels for supplementary assistance. The purpose of the Dataset is to ascertain spatial structures and boundary conditions of water-bearing systems, the conditions and changing laws of recharge, runoff and discharge of the groundwater and the distribution and water-yield property grades of water-bearing rock formations. In this way, the spatial distribution features of groundwater resource in the map sheet area can be comprehensively and visually displayed.

(2) The most direct contents expressed in hydrogeological maps are there to clarify the water-yield property of aquifers along with the distribution and water-yield property grades of water-rich layers, in order to provide theoretical support for the recovery of groundwater. In this Dataset, planar water-yield-property-based zones of aquifers were determined and hydrogeological profiles and 3D hydrogeological structural maps were compiled. Therefore, the spatial structure of water-bearing rock formations and the distribution and depth range of water-rich zones within the map sheet area is intuitively reflected in the Dataset, thus providing a direct foundation and support for scientific implementation of groundwater recovery plans and effective protection of groundwater resources.

(3) The Dataset was developed based on pre-existing data and updated and enriched with hydrogeological data obtained by field surveys. The motion laws of the groundwater are highlighted in the Dataset using the theory on the groundwater system as guidance. Therefore, the Dataset is systematical, uniform and effective. Moreover, water-yield property grades of aquifers and potential geological environmental effects resulting from groundwater recovery are fully taken into consideration during dataset expression in order to ensure sustainable development and utilization of groundwater resources together with the sustainable and healthy development of the ecological environment.

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References

Chen Jun. 2000. Application of MapGIS in the preparation of digital hydrogeological maps[J]. Hydrogeology and Engineering Geology, 27(1): 17−20 (in Chinese with English abstract).

Dang Xueya, Zeng Qingming, Yang Bingchao, Gu Xiaofan. 2018. Dataset of the 1∶50 000 Hydrogeological Map of Gahai Town, Qaidam Basin[J]. Geology in China, 45(S2): 39−50.

Fan Pengfei. 1998. Groudwater Evolution and Prediction in North China Plain[J]. Journal of earth, 19(4): 346−352 (in Chinese with English abstract).

He Jianfeng, Zhou Jinlong. 1989. An compiled overview of the environmental hydrological geological map[J]. Ground Water, (2): 73−75 (in Chinese with English abstract).

Lyu Lin, Li Wei, Liu Yuanqing, Wang Xinfeng, Ma Xuemei, Deng Qijun. 2018. Dataset of the 1∶50 000 Hydrogeological Map of Laiwu City, Shandong Province[J]. Geology in China, 45(S2): 51−62.

Ministry of Land and Resources of the People' s Republic of China. 2014. The specification for hydrogeological well drilling[S]. Beijing: Standards Press of China (in Chinese).

Ministry of Land and Resources of the People' s Republic of China. 2015. Hydrogeological survey specification (1: 50 000)[S]. Beijing: Geological Publishing House (in Chinese).

Pang Jianfeng, Ding Xiaozhong, Han Kunying, Zeng Yong, Chen Anshu, Zhang Yanling, Zhang Qinghe, Yao Dongsheng. 2017. The national 1∶1 000 000 geological map spatial database[J]. Geology in China, 44(S1): 10−23.

Tan Shiyan. 1991. Method of Assessment on Water Yield Property of Rock Formation in Hydrogeological Map[J]. Hydrogeology & Engineering Geology, 18(1): 51−52 (in Chinese with English abstract).

Wang Qi. 1998. Theoritical basis and expressional methods of the compilation of the deposit hydrogeological maps in karst water area in North China[J]. Journal of Xi'an Mining Institute, 18(2): 141−145 (in Chinese with English abstract).

Wu Aimin, Giovanni Conte, Lucio Martarelli, Ma Rong. 2016. Understanding and Discussions on Hydrogeological Map of Italy-Guidelines to Survey and Mapping[J]. Hydrogeology & Engineering Geology, 43(5): 166−172 (in Chinese with English abstract).

Zhang Jianfeng. 1985. Compiling principles and methods of Hydrogeological maps[J]. Hydropower of Northeast, (8): 36−38 (in Chinese with English abstract).