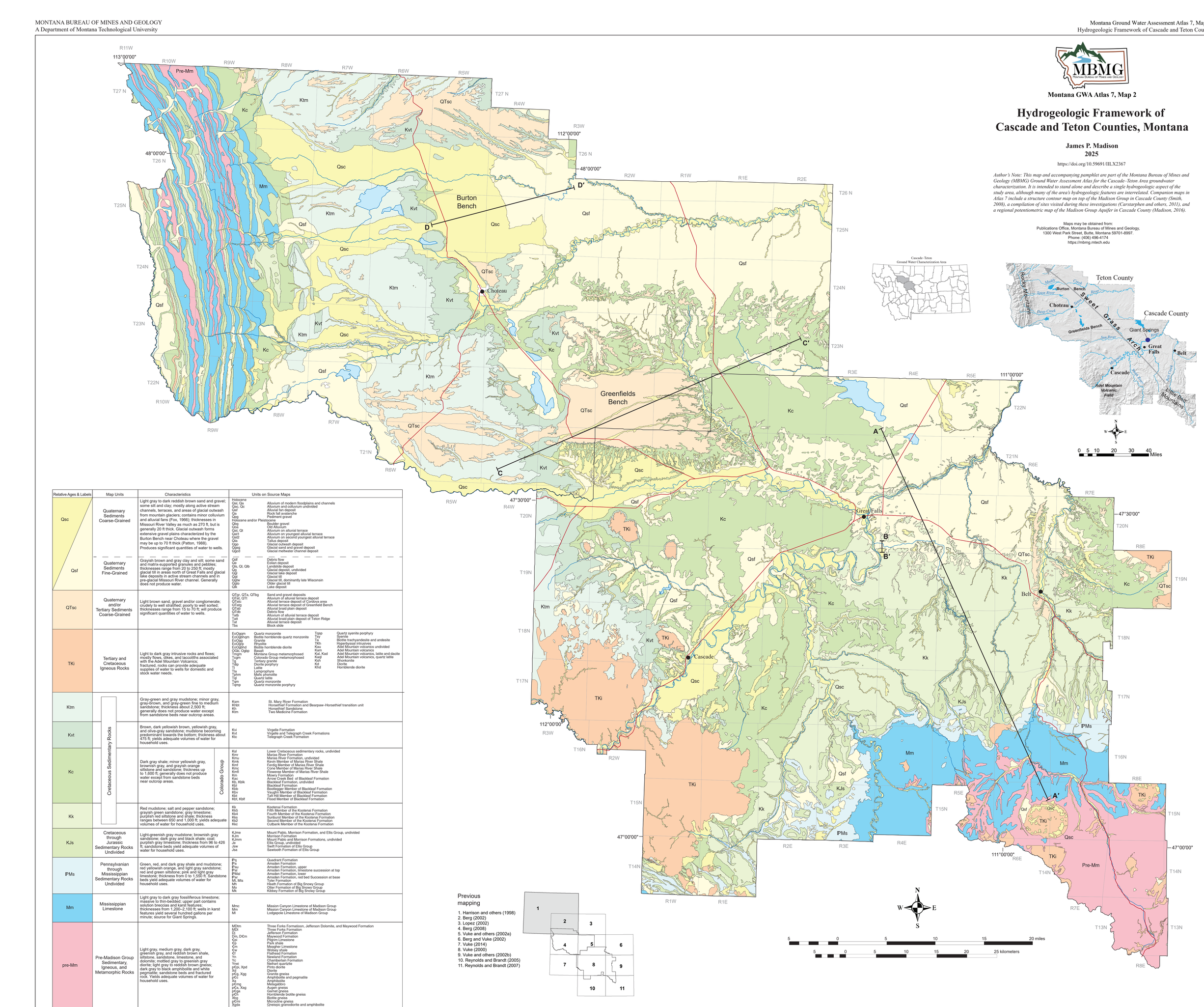
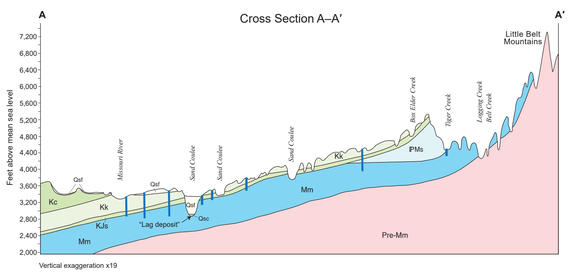
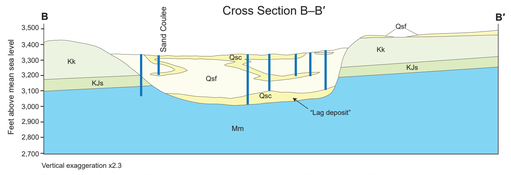


1. Harrison and others (1998)
2. Berg (2002)
3. Lopez (2002)
4. Berg (2008)
5. Vuke and others (2002a)
6. Berg and Vuke (2002)
7. Vuke (2014)
8. Vuke (2000)
9. Vuke and others (2002b)
10. Reynolds and Brandt (2005)
11. Reynolds and Brandt (2007)

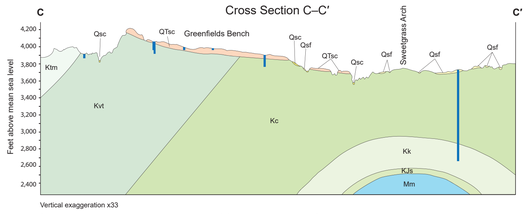
Relative Ages & Labels	Map Units	Characteristics	Units on Source Maps
Qsc	Quaternary Sediments Coarse-Grained	Light gray to dark reddish brown sand and gravel; some silt and clay; mostly along active stream channels, terraces, and areas of glacial outwash from mountain glaciers; contains minor colluvium and alluvial fans (Fox, 1966); thicknesses in Missouri River Valley as much as 270 ft, but is generally 20 ft thick. Glacial outwash forms extensive gravel plains characterized by the Burton Bench near Choteau where the gravel may be up to 70 ft thick (Patton, 1988). Produces significant quantities of water to wells.	Holocene Qal, Qa — Alluvium of modern floodplains and channels Qac, Qc — Alluvium and colluvium undivided Qaf — Alluvial fan deposit Qa — Rock fall avalanche Qpg — Pediment gravel Holocene and/or Pleistocene Qbg — Boulder gravel Qoa — Old Alluvium Qat, Qt — Alluvium on alluvial terrace Qat1 — Alluvium on youngest alluvial terrace Qat2 — Alluvium on second youngest alluvial terrace Qta — Tallus deposit Qgo — Glacial outwash deposit Qgeg — Glacial sand and gravel deposit Qgcd — Glacial meltwater channel deposit
Qsf	Quaternary Sediments Fine-Grained	Grayish brown and gray clay and silt; some sand and matrix-supported granules and pebbles; thicknesses range from 20 to 250 ft; mostly glacial till in areas north of Great Falls and glacial lake deposits in active stream channels and in pre-glacial Missouri River channel. Generally does not produce water.	Qmf — Debris flow Qe — Eolian deposit Qls, Ql, Qlb — Landslide deposit Qg — Glacial deposit, undivided Qgl — Glacial lake deposit Qgt — Glacial till Qgtw — Glacial till, dominantly late Wisconsin Qgto — Older glacial till Qlk — Lake deposit
QTsc	Quaternary and/or Tertiary Sediments Coarse-Grained	Light brown sand, gravel and/or conglomerate; crudely to well stratified; poorly to well sorted; thicknesses range from 15 to 70 ft; will produce significant quantities of water to wells.	QTgr, QTa, QTbg — Sand and gravel deposits QTal, QTt — Alluvium of alluvial terrace deposit QTatc — Alluvial terrace deposit of Cordova area QTatg — Alluvial terrace deposit of Greenfield Bench QTab — Alluvial braid plain deposit QTdb — Debris flow Tatb — Alluvium of alluvial terrace deposit Tatt — Alluvial braid plain deposit of Teton Ridge Tat — Alluvial terrace deposit Tbs — Block slide
TKi	Tertiary and Cretaceous Igneous Rocks	Light to dark gray intrusive rocks and flows; mostly flows, dikes, and laccoliths associated with the Adel Mountain Volcanics; fractured, rocks can provide adequate supplies of water to wells for domestic and stock water needs.	EoQggm — Quartz monzonite EoQgbhgm — Biotite hornblende quartz monzonite EoQgg — Granite EoQgrp — Rhyolite EoQgbhd — Biotite hornblende diorite QGb, Ogbp — Basalt Tmgm — Montana Group metamorphosed Tcgm — Colorado Group metamorphosed Tg — Tertiary granite Tdp — Diorite porphyry Tl — Latite Tla — Lamprophyre Tphm — Mafic phonolite Tql — Quartz latite Tqm — Quartz monzonite Tqmp — Quartz monzonite porphyry Tqsp — Quartz syenite porphyry Tsy — Syenite Ta — Biotite trachyandesite and andesite TKh — Hyperthyssal intrusives Kau — Adel Mountain volcanics undivided Kam — Adel Mountain volcanics Kal, Kad — Adel Mountain volcanics, latite and dacite Kaql — Adel Mountain volcanics, quartz latite Ksh — Shonkonite Kd — Diorite Khd — Hornblende diorite
Ktm	Cretaceous Sedimentary Rocks	Gray-green and gray mudstone; minor gray, gray-brown, and gray-green fine to medium sandstone; thickness about 2,500 ft; generally does not produce water except from sandstone beds near outcrop areas.	Ksm — St. Mary River Formation Khbt — Horsethief Formation and Bearpaw–Horsethief transition unit Kh — Horsethief Sandstone Ktm — Two Medicine Formation
Kvt		Brown, dark yellowish brown, yellowish gray, and olive-gray sandstone; mudstone becoming predominant towards the bottom; thickness about 475 ft; yields adequate volumes of water for household uses.	Kvi — Virgelle Formation Kvt — Virgelle and Telegraph Creek Formations Ktc — Telegraph Creek Formation
Kc		Dark gray shale; minor yellowish gray, brownish gray, and grayish orange siltstone and sandstone; thickness up to 1,600 ft; generally does not produce water except from sandstone beds near outcrop areas. (Colorado Group)	Ksl — Lower Cretaceous sedimentary rocks, undivided Kmr — Marias River Formation Kmu — Marias River Formation, undivided Kmk — Kevin Member of Marias River Shale Kmf — Ferdig Member of Marias River Shale Kmc — Cone Member of Marias River Shale Kmfl — Floweree Member of Marias River Shale Km — Mowry Formation Kac — Arrow Creek Bed of Blackleaf Formation Kb, Kblk — Blackleaf Formation, undivided Kbl — Blackleaf Formation Kbb — Bootlegger Member of Blackleaf Formation Kbv — Vaughn Member of Blackleaf Formation Kbt — Taft Hill Member of Blackleaf Formation Kbf, Kblf — Flood Member of Blackleaf Formation
Kk		Red mudstone; salt and pepper sandstone; grayish green sandstone; gray limestone; purplish red siltstone and shale; thickness ranges between 650 and 1,000 ft; yields adequate volumes of water for household uses.	Kk — Kootenai Formation Kk5 — Fifth Member of the Kootenai Formation Kk4 — Fourth Member of the Kootenai Formation Kks — Sunburst Member of the Kootenai Formation Kk2 — Second Member of the Kootenai Formation Kkc — Cutbank Member of the Kootenai Formation
KJs	Cretaceous through Jurassic Sedimentary Rocks Undivided	Light-greenish gray mudstone; brownish gray sandstone; dark gray and black shale; coal; purplish gray limestone; thickness from 96 to 426 ft; sandstone beds yield adequate volumes of water for household uses.	KJme — Mount Pablo, Morrison Formation, and Ellis Group, undivided KJm — Morrison Formation KJmm — Mount Pablo and Morrison Formations, undivided Je — Ellis Group, undivided Jsw — Swift Formation of Ellis Group Jsa — Sawtooth Formation of Ellis Group
IPMs	Pennsylvanian through Mississippian Sedimentary Rocks Undivided	Green, red, and dark gray shale and mudstone; red yellowish orange, and light gray sandstone; red and green siltstone; pink and light gray limestone; thickness from 0 to 1,550 ft. Sandstone beds yield adequate volumes of water for household uses.	IPq — Quadrant Formation IPa — Amsden Formation IPau — Amsden Formation, upper IPal — Amsden Formation, limestone succession at top IPAal — Amsden Formation, lower IPar — Amsden Formation, red bed Succession at base Mt, Mts — Tyler Formation Mh — Heath Formation of Big Snowy Group Mo — Otter Formation of Big Snowy Group Mk — Kibbey Formation of Big Snowy Group
Mm	Mississippian Limestone	Light gray to dark gray fossiliferous limestone; massive to thin-bedded; upper part contains solution breccias and karst features; thicknesses from 1,200–2,100 ft; wells in karst features yield several hundred gallons per minute; source for Giant Springs.	Mmc — Mission Canyon Limestone of Madison Group Mm — Mission Canyon Limestone of Madison Group Ml — Lodgepole Limestone of Madison Group
pre-Mm	Pre-Madison Group Sedimentary, Igneous, and Metamorphic Rocks	Light gray, medium gray, dark gray, greenish gray, and reddish brown shale, siltstone, sandstone, limestone, and dolomite; mottled gray to greenish gray diorite; light gray to reddish brown gneiss; dark gray to black amphibolite and white pegmatite; sandstone beds and fractured rock. Yields adequate volumes of water for household uses.	MDtm — Three Forks Formatioon, Jefferson Dolomite, and Maywood Formation MDt — Three Forks Formation Dj — Jefferson Formation Dm, DCm — Maywood Formation Cpi — Pilgrim Limestone Cp — Park shale Cm — Meagher Limestone Cw — Wolsey shale Cf — Flathead Formation Yn — Newland Formation Yc — Chamberlain Formation Ynei — Neihart quartzite pCpi, Xpd — Pinto diorite Xd — Diorite pCg, Xgg — Granite gneiss pCc — Amphibolite and pegmatite Xa — Amphibolite pCmg — Metagabbro pCa, Xag — Augen gneiss pCga — Garnet gneiss pCh — Hornblende biotite gneiss Xbg — Biotite gneiss pCmi — Microcline gneiss Xgda — Gneissic granodiorite and amphibolite Wd — Metadiorite



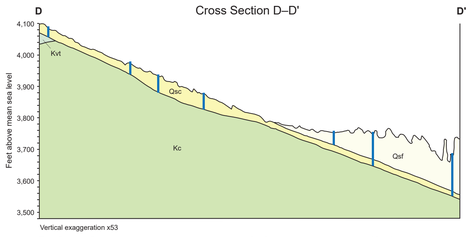
The Madison Group (Mm) crops out in the Little Belt Mountains and dips gently to the north into the subsurface. Most wells between the Little Belt Mountains and Great Falls are completed in either the Madison Group (Mm) or Kootenai Formation (Kk).



The ancestral Missouri River carved through Kootenai (Kk), Morrison, and Swift (KJs), and into the Madison Limestone. The valley was subsequently filled by Glacial Lake Great Falls silt and clay (Qsf) and other coarser sediments (Qsc).



Shale units (Kc and Ktm) underlie most of Cascade and Teton Counties and are not considered regional aquifers. Few wells tap deeper hydrogeological units considered aquifers, such as Kk or Mm, because of depth (cost) and potential for poor water quality.



The Burton Bench is underlain by less than 100 ft of glacial outwash gravel (Qsc), mostly resting on the Colorado Group (Kc). Groundwater is recharged mostly by leakage from canals and irrigated fields. Gravels become buried and confined by glacial lake silts and till (Qsf).

Montana GWA Atlas 7, Map 2

Hydrogeologic Framework of Cascade and Teton Counties, Montana

James P. Madison

2025

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Author's Note: This map and accompanying pamphlet are part of the Montana Bureau of Mines and Geology (MBMG) Ground Water Assessment Atlas for the Cascade–Teton Area groundwater characterization. It is intended to stand alone and describe a single hydrogeologic aspect of the study area, although many of the area's hydrogeologic features are interrelated. Companion maps in Atlas 7 include a structure contour map on top of the Madison Group in Cascade County (Smith, 2008), a compilation of sites visited during these investigations (Carstarphen and others, 2011), and a regional potentiometric map of the Madison Group Aquifer in Cascade County (Madison, 2016).

Maps may be obtained from:
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