MN DEPT OF NATURAL RESOURCES

Yellow Medicine River Hydrologic Analysis

An Addendum to the MPCA WRAPS Report

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Hydrology

Hydrologic conditions (*e.g.,* precipitation, runoff, storage, and annual water yield) and the disturbance of natural pathways (*e.g.,* tiling, ditching, land use changes, and loss of water storage) has become the driver of many impairments in other Minnesota watersheds (MPCA 2012). These disturbances coupled with an increase in precipitation (*i.e.,* total, frequency, and magnitude) have resulted in issues with: increased bank erosion, excess sediment, habitat degradation, and disturbance of natural flow regime.

Hydrologic modification is the alteration or addition of water pathways and associated changes in volume by human activity. Those modifications can dramatically alter discharge due to changes in volume, timing, connectivity, or flow rates, particularly if the area was not a flow pathway in the past. The types of hydrologic modifications are vast, including the draining and filling of wetlands and lakes, ditching or draining formerly hydrologically disconnected basins, adding impervious surfaces across the basin, increasing drainage for increased transport of water (*i.e.,* in urban and agricultural areas), straightening or constricting a natural flow path or river, and changing the timing and rate of delivery within the hydrologic system. Any increase in stream power (*e.g.,* due to change in peak flows or increased frequency of bank full flows) will generate an increase in water yield (Lane 1955).

Reduced surface storage, increased conveyance, increased effective drainage area along with altered crop rotations supporting soybeans over perennial grasses and small grains have all altered the dynamics of and generally increased the annual water discharged from these watersheds while also dramatically altering the return interval for various flow stages (Schottler 2014).

In extensively drained landscapes, such as the agricultural Midwest of the United States, the connection of isolated basins has inflated total surface water discharge and increased the density of linear drainage networks (Ter Haar & Herricks, 1989, Haitjema 1995, Magner et al. 2004). Many streams in the region are in disequilibrium due to past and current land-use change with corresponding hydrologic responses, as well as direct channel modifications (Lenhart 2007).

These modifications have not occurred at a constant rate, but in episodes or events, such as construction of the public drainage system from 1912-1920 (Lenhart 2007, 2008) and continue today through repair, upgrade, and increased amount of impervious surfaces and subsurface drainage. Construction of subsurface tile and surface ditch drainage systems in the early 1900s increased contributing drainage areas, resulting in greater amounts of water delivered to rivers (Leach and Magner 1992, Kuehner 2004, Lenhart 2008). The effects of these suites of changes are cumulative, interrelated, and tend to compound across different spatial and temporal scales (Spaling & Smit 1995, Aadland et al. 2005, Blann et al. 2009). The contribution of subsurface drainage to aquatic ecosystem affects may be difficult to isolate relative to other agricultural impacts (Blann et al. 2009). Cumulatively, these changes in hydrology, geomorphology, nutrient cycling, and sediment dynamics have had profound implications for aquatic ecosystems and biodiversity (Blann et al. 2009).

The hydrologic analysis found in this report focuses on surface-water components of the hydrologic cycle, rainfall-runoff relationships, open-channel flow, flood hydrology, and statistical and probabilistic methods in hydrology.

Hydrology Methods

In order to understand and evaluate the hydrologic processes within a watershed, several types of analysis are used to examine the relationships between flow (discharge) and precipitation. Ground water levels and usage over time is also reviewed. The analysis methods can evaluate and measure changes within a system by reviewing statistical variations and trends over time.

Discharge Analysis

Flow/discharge data sets are collected by the USGS and MPCA/DNR stream gage network for the various watersheds. Site specific stream flow data is calculated using continuous stream stage measurements and periodic stream flow measurements. This data is plotted and charted to allow for statistical analysis and is used to create hydrographs, flow duration curves and other visual representations of the period of record.

Watershed discharge data can be used to review daily, monthly, seasonal, annual and long term trends within a watershed as examine changes in the discharge characteristics such as periods of low or zero flow, flood frequency, base flow volume, and seasonal variability. Discharge data from the Yellow Medicine River was collected at Granite Falls, from USGS site 05313500.

Precipitation

Precipitation data is based on the long term data collection location nearest to the stream data collection site. All precipitation data is acquired through the "High Density Radius Retrieval" website maintained by the Minnesota State Climatology Office. Precipitation data is used to examine long term trends within a watershed, and the relationship and response of discharge, runoff, and baseflow conditions relative to recorded precipitation totals. Long-term precipitation data was available at Granite Falls, Minnesota (Station #213311).

Double Mass Curve

A Double Mass Curve is an analysis based on a cumulative comparison of one independent variable with a cumulative dependent variable. This is useful in hydrologic data as it allows the examination of the relationship between two variables. This technique was used to compare precipitation and stream discharge relationships (annual and seasonal) and well elevation fluctuations relative to precipitation. When plotted, a straight line indicates consistency in the relationship, a break in the slope would mean a change in the relationship.

When used with long term discharge data sets, the curve can demonstrate when the change in the relationship began to occur. All double mass curves presented are runoff (Discharge/Watershed area) and monthly precipitation in inches. All discharge values are converted to inches by dividing total volume by the watershed area (the annual discharge converted to acre–ft. and then to inches of runoff over the watershed). Additional information on double mass curve development and interpretation can be found on the following website: http://pubs.usgs.gov/wsp/1541b/report.pdf

Hydrology

Stream data collection at Granite Falls began in 1931 through the USGS and is currently operating with no break in the discharge data. This long term data set (>30 years) allows for in-depth analysis of changes over time. Long term data allows for better analysis within a watershed and can help show trends or pinpoint when relationships began in to change. Additional data including daily, monthly, annual and peak flow statistics have been computed and complied by the USGS for the site.

Discharge Analysis

All discharge data was plotted out using monthly and annual average flow values for the period of record to create a hydrograph. A hydrograph is a chart showing the rate of flow (*i.e.* discharge) over time at a sample location. Once plotted, the data can be examined for changes over time. Looking at the monthly flow values over time, average discharge volumes have increased (Figure 1).

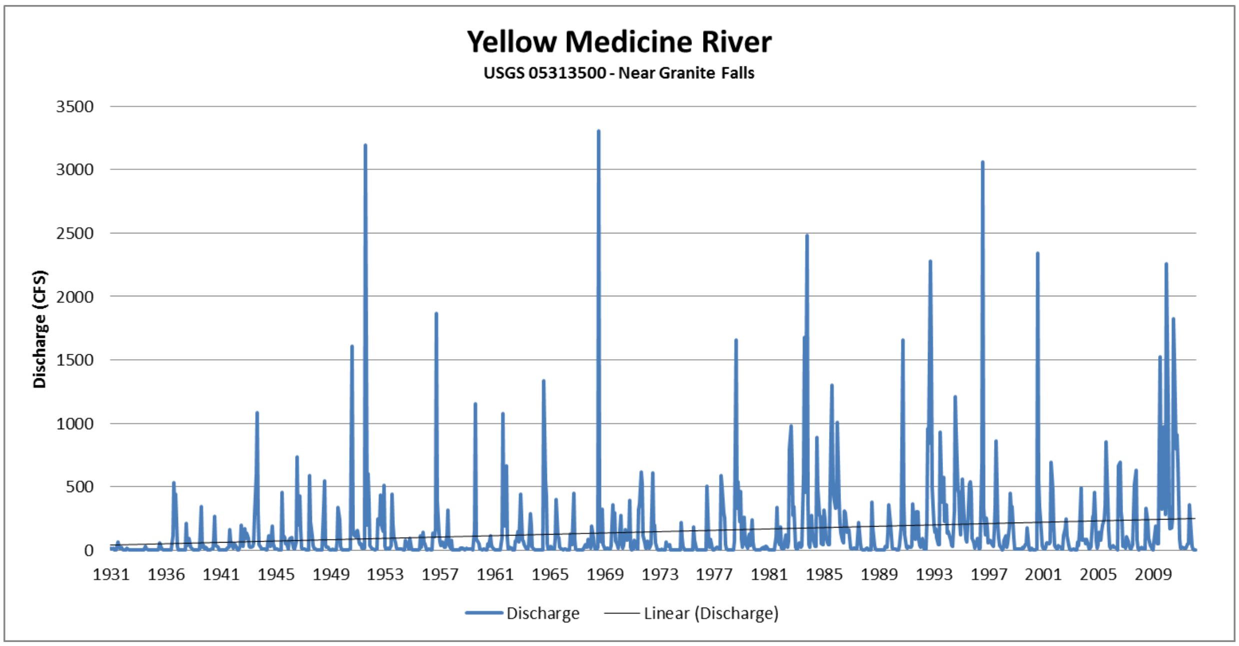

Figure 1 – Yellow Medicine River Hydrograph

To further examine this increase in discharge volumes, precipitation trends were examined in relationship to monthly discharge volumes over the total watershed and in annual total discharge versus total precipitation (Figure 2). General precipitation trends will also be examined in the next section.

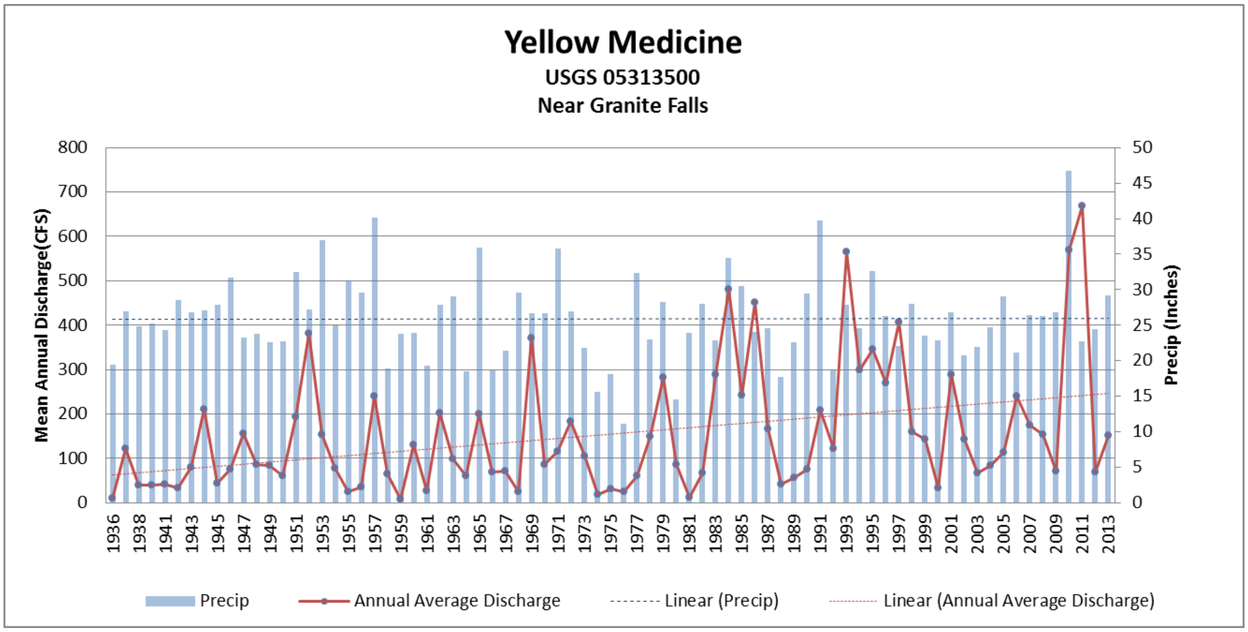

Figure 2 – Annual discharge and precipitation

The hydrograph (Figure 1) depicts mean annual discharge and monthly precipitation totals over time. This also shows that while runoff volumes are increasing, precipitation is staying steady over the period of record. When plotted out looking at total annual discharge and precipitaion totals, the change in the relationship over time becomes more apparent (Figure 2).

Discharge data is also used to create a duration curve (Figure 3). Duration curves are used to examine the discharges and determine when a specific flow volume was exceeded or equaled in a given period, such as how often the flow volume exceeds high (*i.e.* 10^{th} percentile) and low (*i.e.* 90^{th} percentile) flow conditions for the watershed.

A curve with a steep slope throughout indicates a highly variable stream whose discharge is derived from direct runoff. A flat slope indicates the potential presence of surface or ground-water storage, which can help meter out the flow at a slower rate. The curve for the Yellow Medicine is more flat. It should be noted however that while the low flow conditions (*i.e.* < Q_{90}) do have a high slope, no zero flow conditions are recorded. This indicates that while a negligible amount of perennial storage exists within the watershed, there is likely some level of ground water interaction with the river system at low flows.

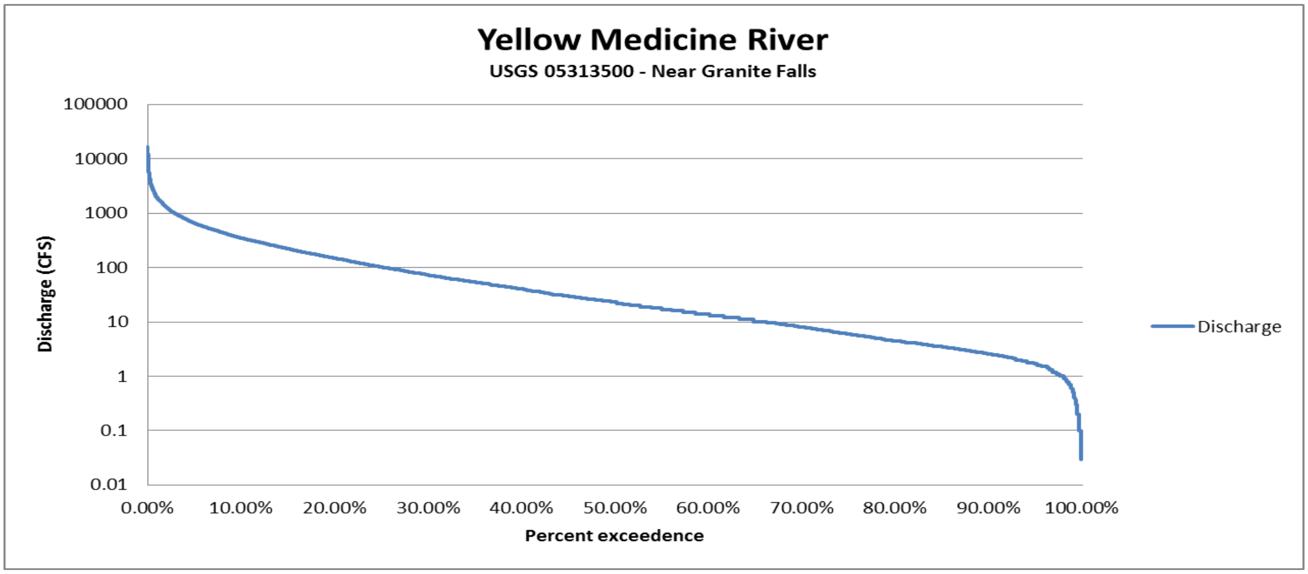

Figure 3 – Yellow Medicine flow duration curve

Using the duration data, trends can be analyzed for various flow conditions. The high flow (*i.e.* Q_{10}) and low flow (*i.e.* Q_{90}) periods were plotted to examine if the number of days at the flow conditions has changed over time. It both cases, both the high and low flow conditions have changed over time. The number of days at or below low flow (*i.e.* Q_{90}) conditions has gone down over time, while the number of days at high flows (*i.e.* Q_{10}) has increased over time (Figure 4).

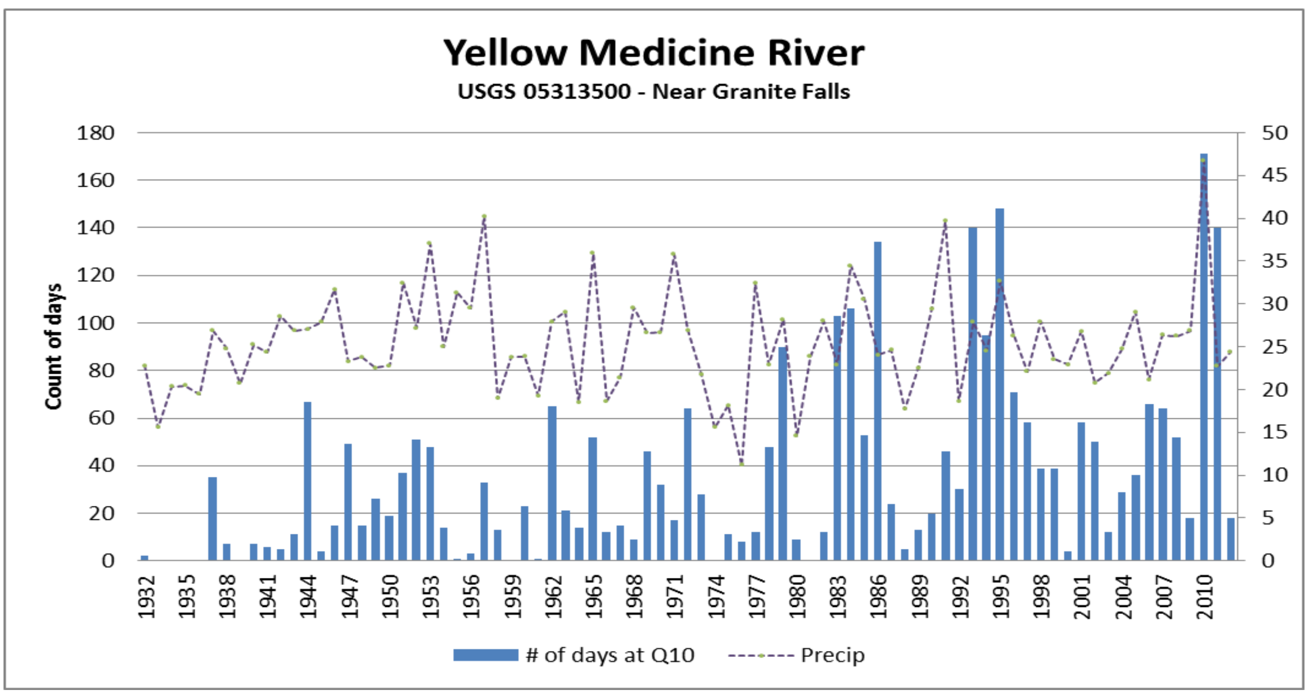

Figure 4 – Days at Q10

Precipitation

Data collected at Granite Falls indicates that the area had dry to drought conditions until approximately 1940. Since then the yearly precipitation totals have been widely variable, with higher than average precipitation in the late 1950s, and lower than average in the early 2000s and the lowest recoded annual value in 1976 (11.18”). It should be noted that the highest annual precipitation total was recorded in 2010 (46.7”). Even with the variability of the annual total values, the seven year average is largely within the 25th-75th percentile values, indicating fairly stable precipitation in the region.

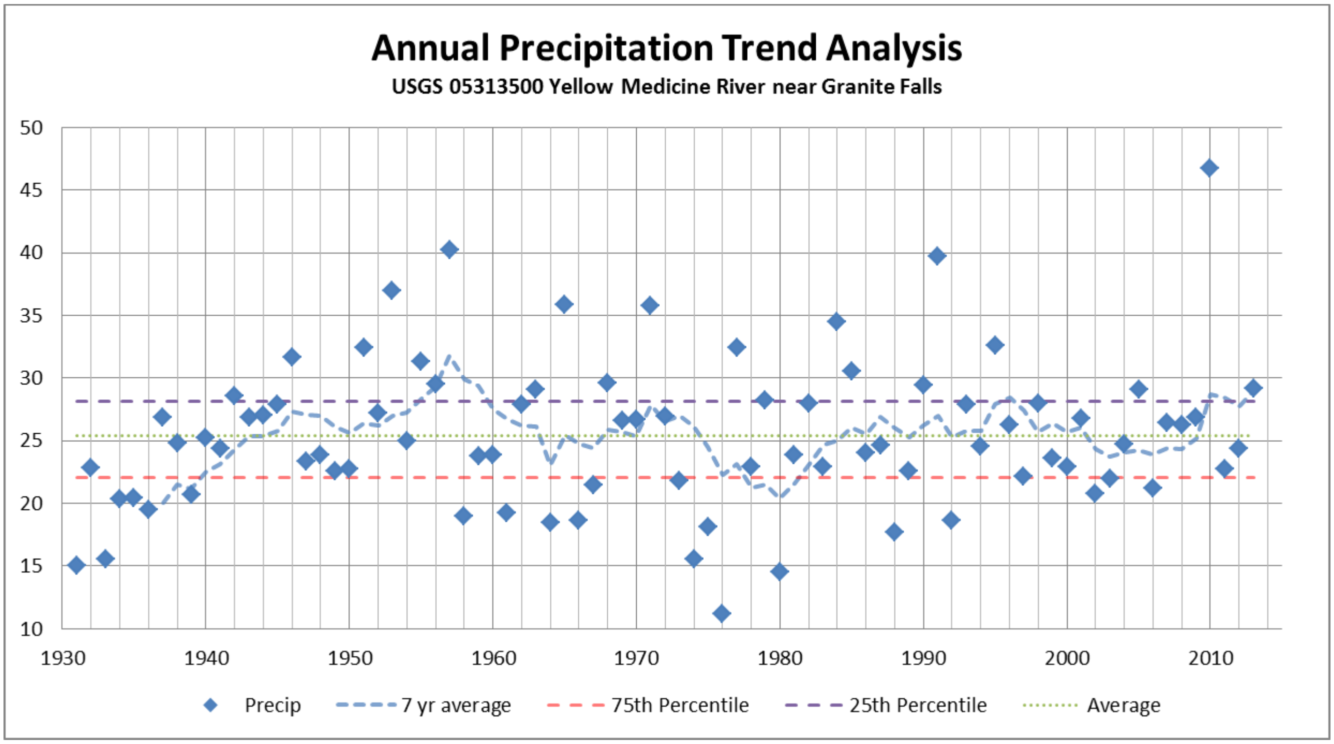

Figure 5 – Precipitation Trends

Precipitation and discharge data are used to develop the double mass curve to examine the relationship between precipitation and discharge.

Double Mass Curve

Double mass curves (DMC) were developed for the Yellow Medicine River data. Precipitation and discharge data are used to develop the double mass curve to examine the relationship between precipitation and discharge. This technique was used to compare precipitation and stream discharge relationships (*i.e.* annual and seasonal) over the period or record (Figure 6). Precipitation was collected from the Granite Falls precipitation data station. When plotted, a straight line indicates consistency in the relationship, a break in the slope would mean a change in the relationship.

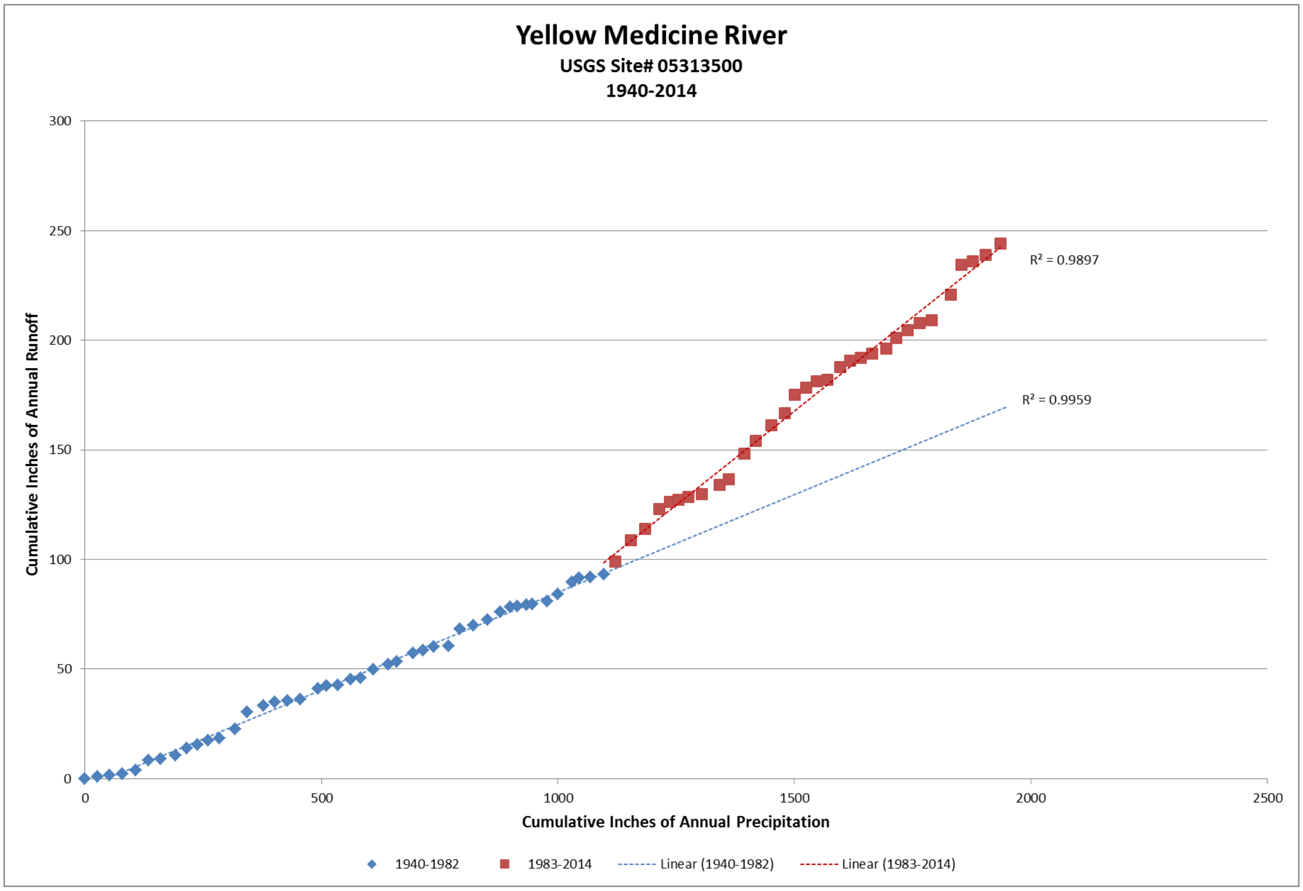

Figure 6 – Double mass curve for Yellow Medicine near Granite Falls

The curve shows a fairly constant relationship between runoff and precipitation during the 1940 to 1982 period and again from 1983 to 2012, with the variability accounted for annual precipitation totals. This change in the relationship indicates runoff is increasing relative to the amount of rain. Within the entire data set, both low and high annual precipitation volumes were recorded suggesting that a period of wet or dry conditions does not affect this relationship.

The two periods of record can also be plotted out as average annual discharge (Figure 7). While this does condense the data, it is useful to examine the change between the average values. As seen in Figure 14, the average value has changed in both volume and timing.

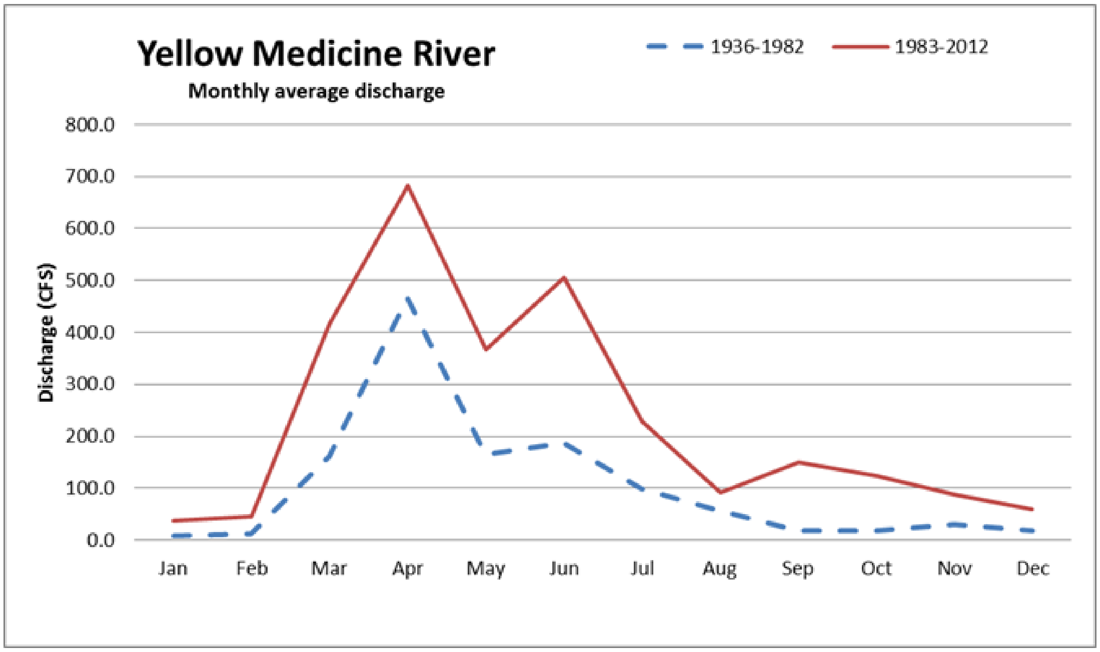

Figure 7 – Yellow Medicine River monthly average discharge

Ground Water Usage

Lastly, groundwater usage for the watershed was reviewed by compiling all reported permitted usage. All permit data was collected through the State Water Use Data System (SWUDS). The largest appropriation/usage category in the Yellow Medicine River watershed is municipal waterworks. Livestock watering has shown the most consistent upward trend in usage over time.

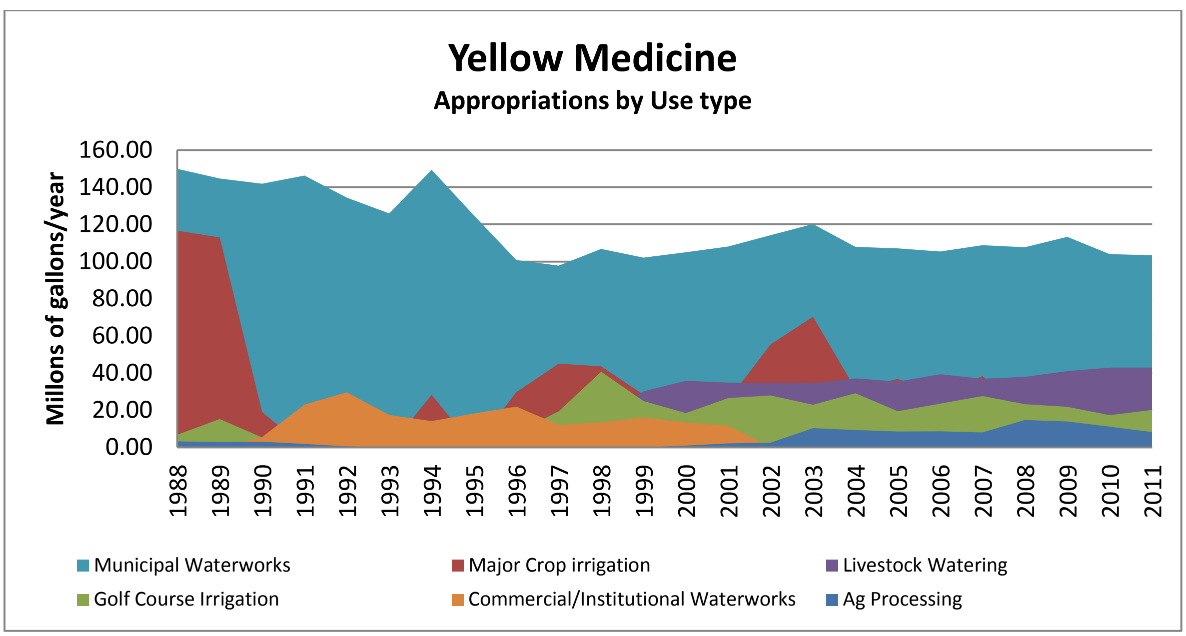

Figure 8 – Water appropriations by type

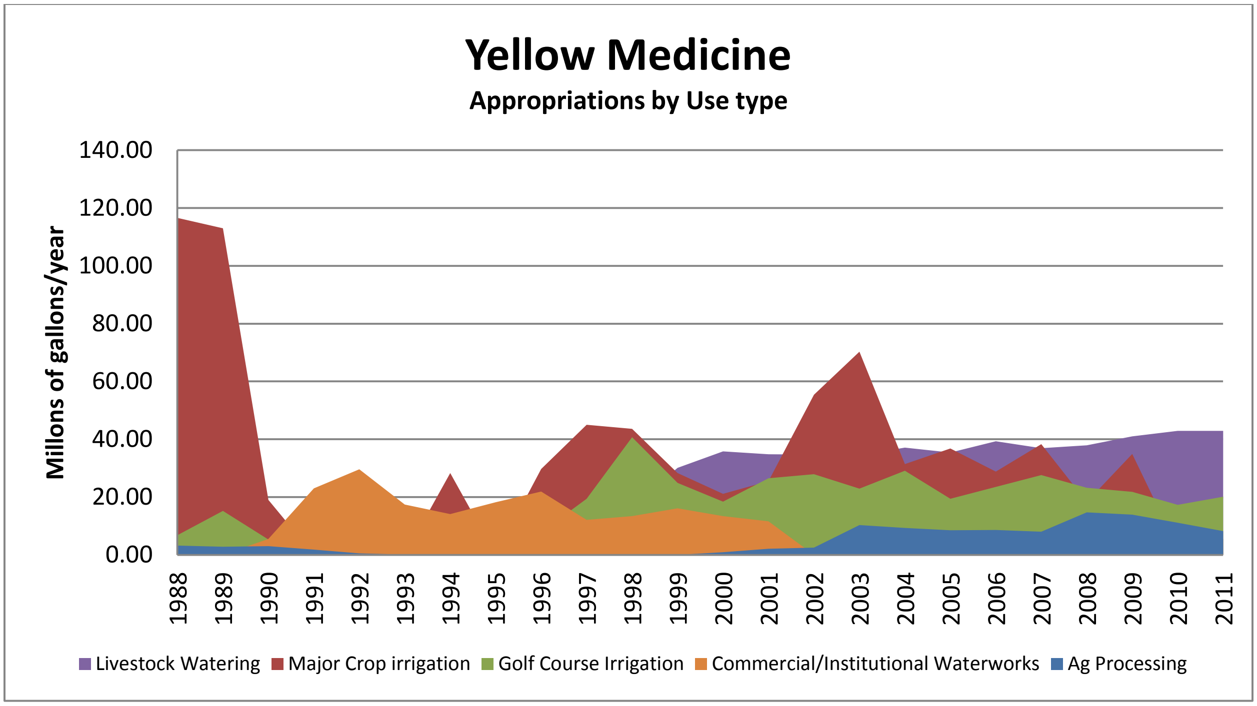

Figure 9 – Water appropriations by type

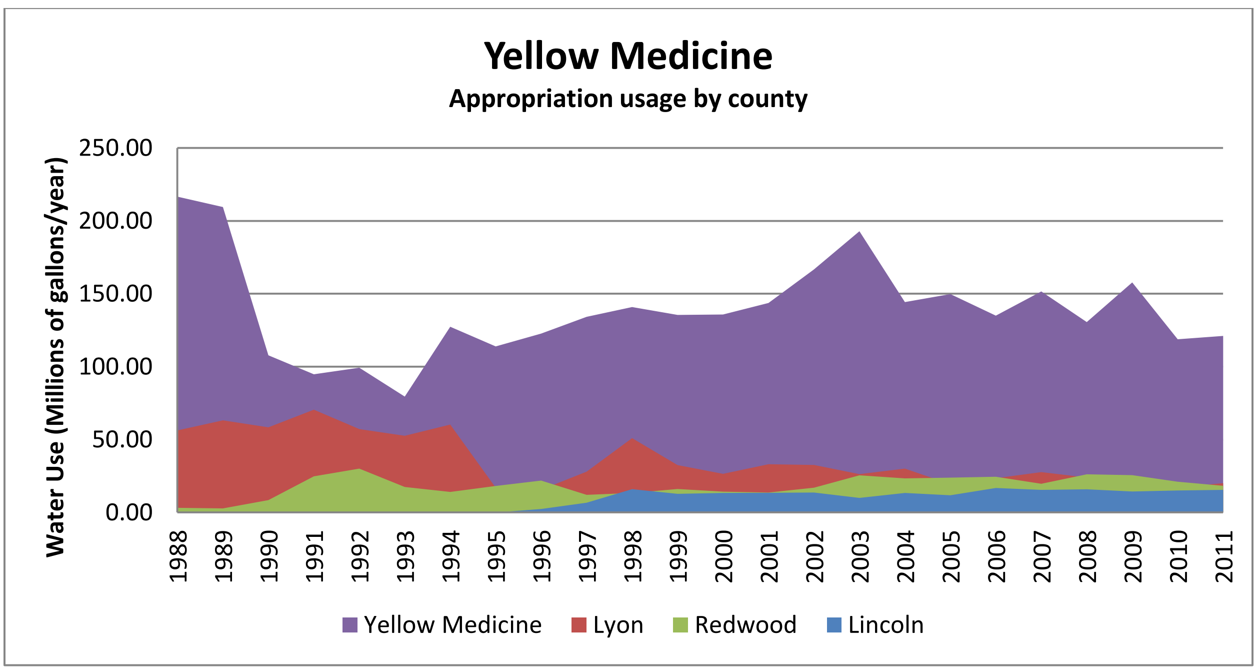

Figure 10 – Annual water appropriations by county

When the total appropriated volume is reviewed by county area, Yellow Medicine County has the highest volume. This is likely due to the County being the vast majority of the watershed.

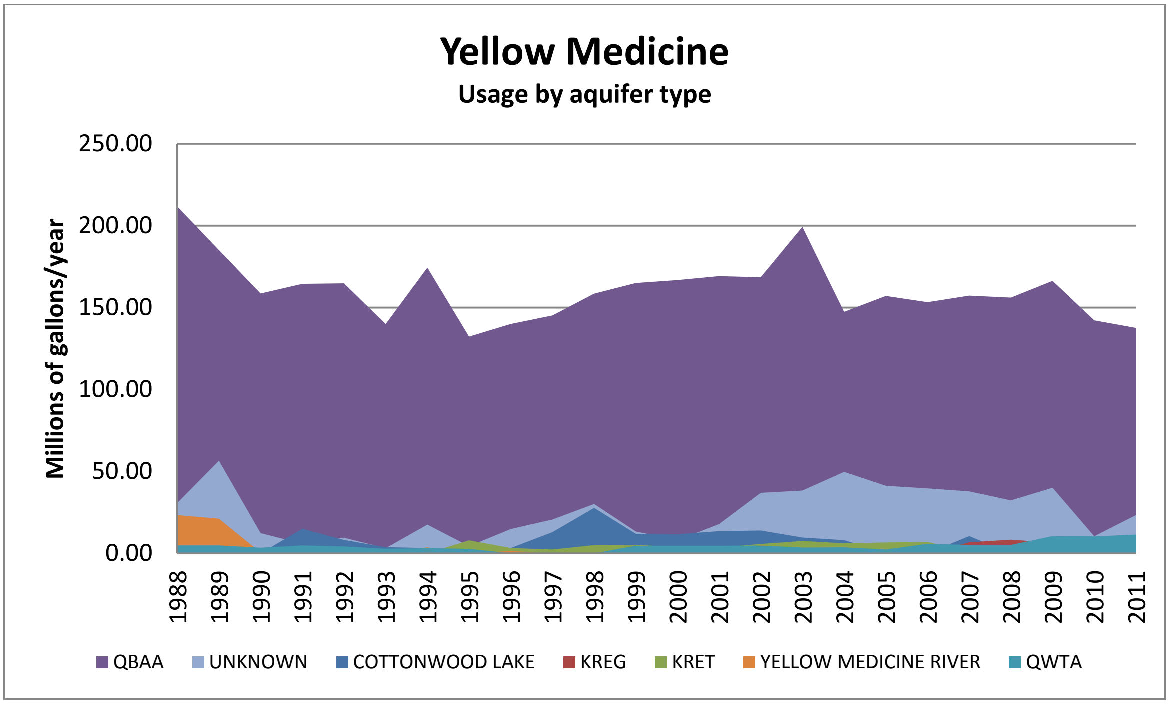

Figure 11 – Annual usage by aquifer

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