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December 2011

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Public Water-Supply Wells on Pilgrim Creek and Potential for Groundwater Pumping to Impact Streamflow, Grand Teton National Park

History of Water Development

Prior to 1961, the primary water supply for Colter Bay and Jackson Lake Lodge developments was obtained from diversion of spring water (NE¼ Sec.20, T46N, R114W, unsurveyed) on the east side of the Pilgrim Creek valley, north of the park boundary. The water was transported in pipelines to two 500,000 gallon covered storage reservoirs; one near Colter Bay and the other near Jackson Lake Lodge. During peak season, the flow of the spring (average 140 gpm) was insufficient to meet the demand. At these times, a supplemental supply of about 200 gpm for Jackson Lake Lodge was obtained from a group of springs in a seep area just east of the lodge (45-114-8ca).

Water use at Colter Bay and Jackson Lake Lodge was increasing steadily, and shortages were occurring regularly. The Park Service was interested in finding a permanent source to supplement the supply from the spring on Pilgrim Creek. There may also have been a desire to switch from a spring source to a groundwater source, as water from the groundwater source would be less susceptible to contamination. [There are often various openings in a spring collection system that might allow insects, rodents, etc. to enter the water system.] In 1961, the Park Service began a hydrogeologic investigation to identify potential locations for well construction and constructed test wells.

Hydrogeology

Most of the area along the eastern shore of Jackson Lake (between Jackson Lake and the Pilgrim Creek fan) is underlain by glacial moraine deposits. Glacial moraine is mostly unsorted till, containing a heterogeneous mix of glacial sediments ranging from clay and silt to boulders. The large amount of fine-grained sediments included in the till causes it to have low permeability. Thus, it is not a productive aquifer. Wells constructed in this area might produce from a few gpm to possibly a few tens gpm, but generally well yields will be low.

Bedrock outcropping to the north of the Pilgrim Creek fan is primarily volcanic tuff deposits, which generally have low permeability. East of the Pilgrim Creek fan, there are more glacial moraine deposits and bedrock outcrops of volcanic tuff deposits.

The only good target for construction of large-yield wells is the alluvial deposits associated with Pilgrim Creek. Streamflow in Pilgrim Creek continually reworks the underlying glacial deposits

and sediments being carried by the creek. Running water transports the fine-grained portion of the sediment downstream to Jackson Lake, leaving behind the coarser sands and gravels and creating a very permeable aquifer filling the valley.

The area covered by the Pilgrim Creek fan was probably deeply scoured by the glaciers. Subsequently, the glacial troughs were filled with coarse-grained sediments, creating a permeable valley-fill aquifer. This filling was likely particularly prolific when the glaciers were melting and streamflow and sediment transport were at their peak.

The general geologic map from McGreevy and Gordon (1964) shows the relationship of the alluvium filling the Pilgrim Creek valley being bounded by glacial till to the east and west and relatively impermeable bedrock to the north (Figure 1).

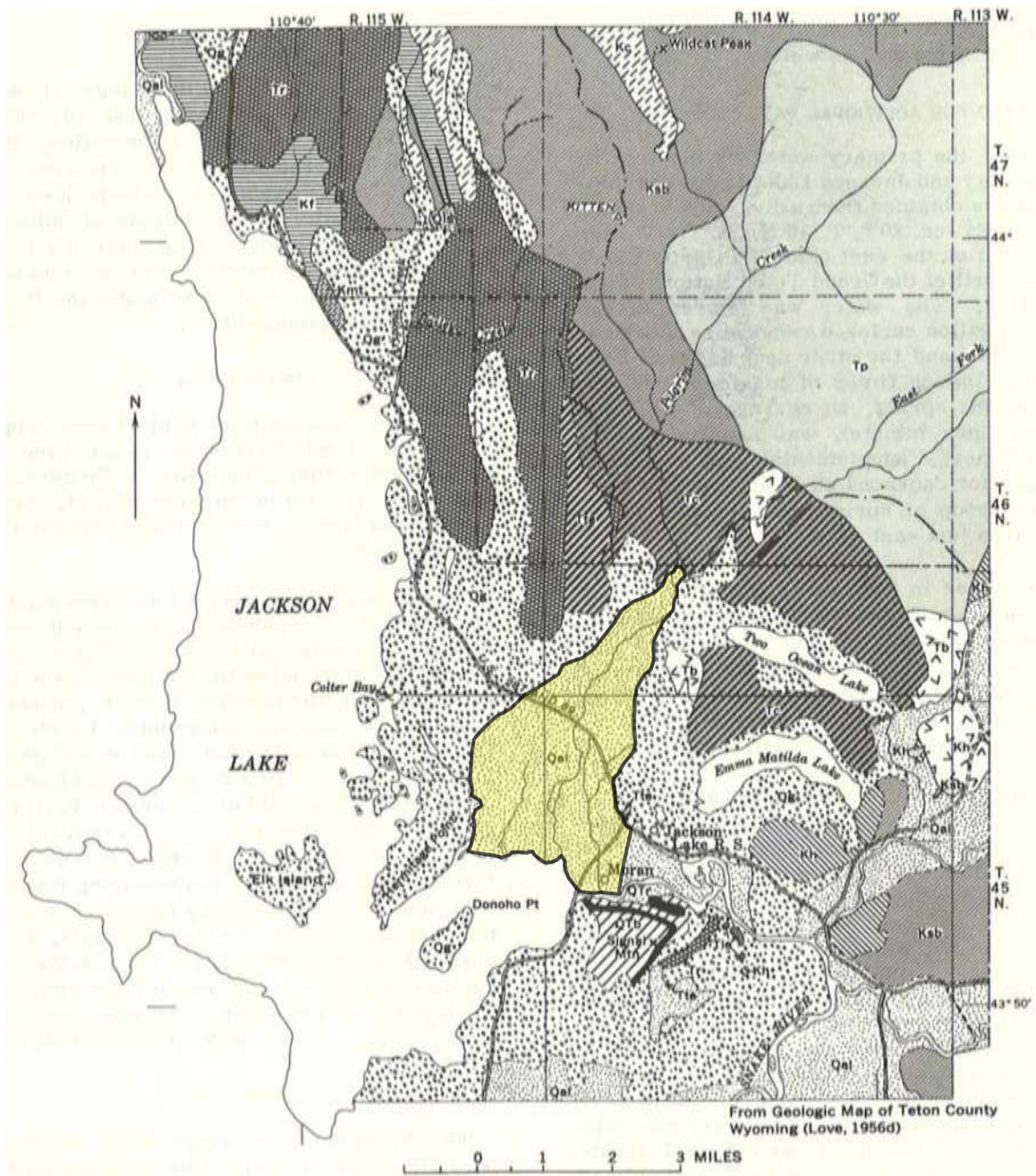


Figure 1. General geologic map of the area east of Jackson Lake with the Pilgrim Creek alluvial fan highlighted in yellow. From McGreevy & Ellis, 1964

1961 Test Wells

In 1961, three test wells were drilled in the upper Pilgrim Creek valley about 3 miles north of Jackson Lake Lodge (Figure 2). The wells ranged from 70-150 deep and encountered unconsolidated sediments consisting of poorly sorted sand and gravel and containing only minor amounts of silt and clay. The wells were located a short distance downstream of the confluence of the main stem of Pilgrim Creek and the East Fork of Pilgrim Creek.

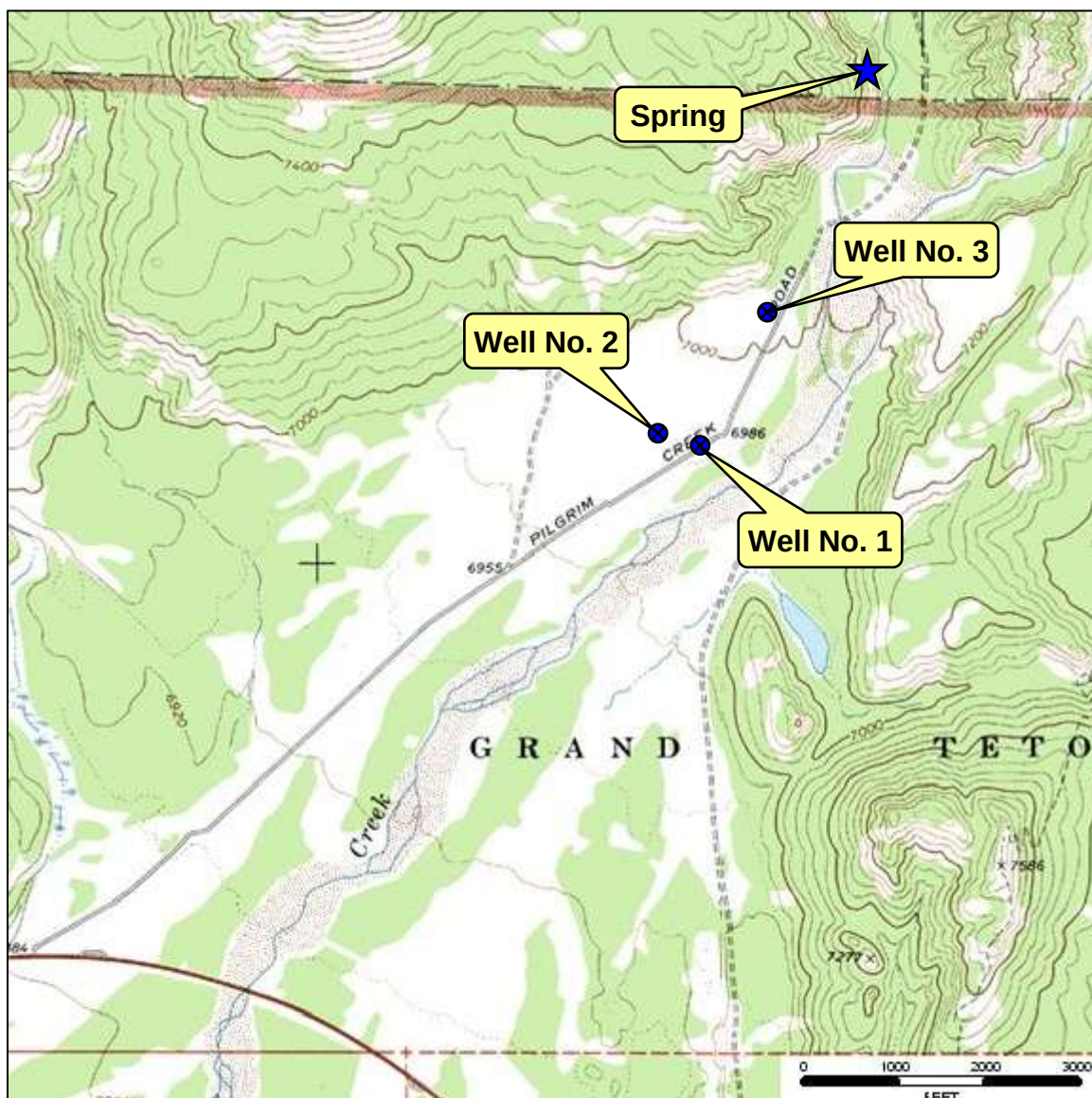


Figure 2. Locations of 1961 test wells and the spring that supplied water to NPS facilities at Colter Bay and Jackson Lake Lodge prior to construction of the well in 1962.

Test Well No. 1 (46-114-29dbd) and Test Well No. 2 (46-114-29dbc) were located 0.4 mile farther downstream of the confluence of the east and west forks of Pilgrim Creek and 200 and 700 feet respectively west of the high-water bank. Test Well No. 3 (46-114-29adc) was 500 feet

downstream from the confluence and 50 feet west of the high-water bank. [The location of the confluence changes periodically in response to natural geomorphology changes of the creek.] Test Well No. 1 was completed with 6-inch steel casing with many perforated intervals and was used as the pumping well for testing. The other two wells, 29adc and 29 dbc were completed with $\frac{3}{4}$ " steel pipe and used as observation wells during pumping tests.

Water levels were monitored in the original three test wells through the summer of 1961 and 1962 when there was no groundwater pumping in the area (Figure 3). The water table in this area dropped about 35 feet from mid-June to mid-October. The observed water level changes are entirely natural, as there was no groundwater pumping in the area at that time.

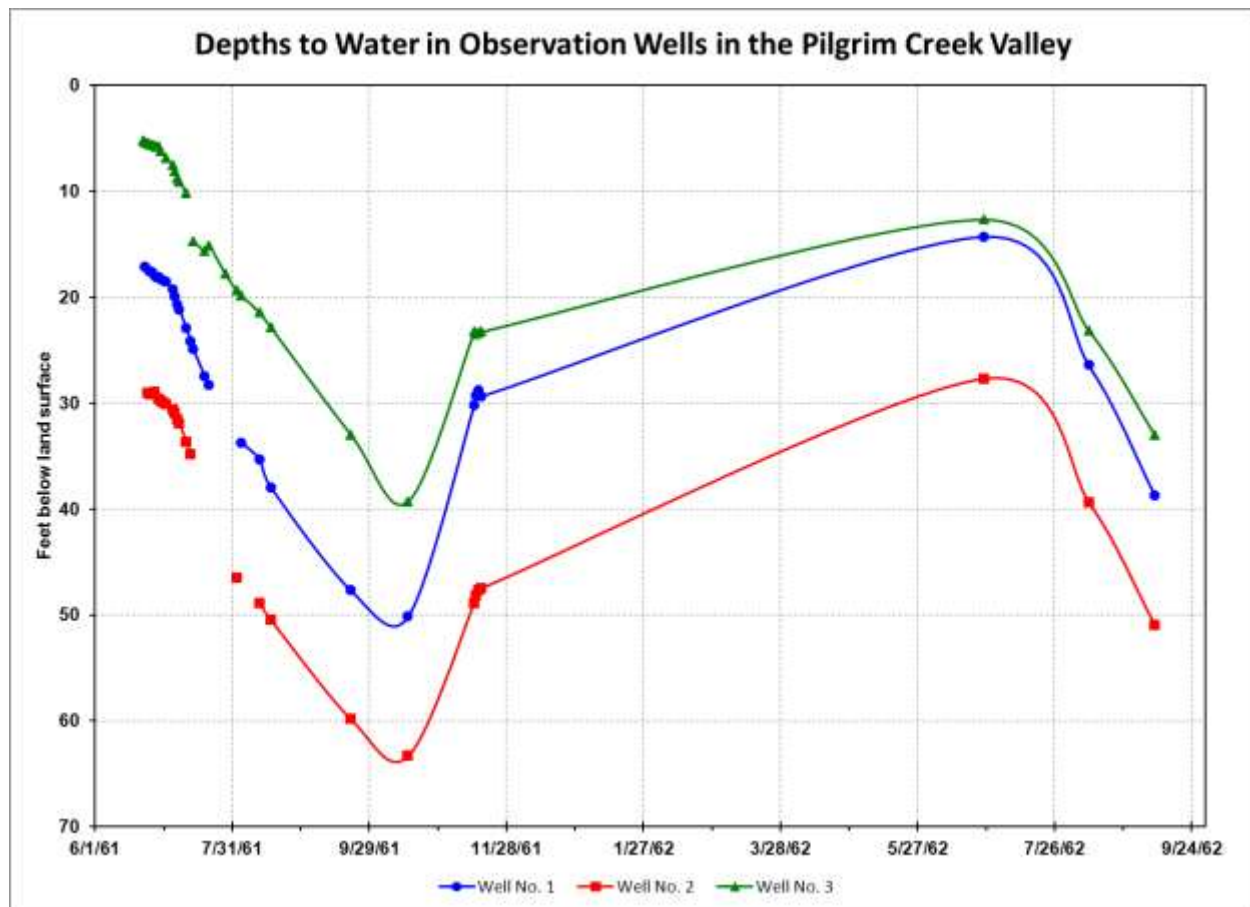


Figure 3. Depth to water in test wells in the Pilgrim Creek alluvial fan, 1961-62.

Cox (1974) measured groundwater levels in the three Pilgrim Creek Test Wells during the summer months (June – October) from 1967-72 (Figure 4). These measurements were made at the test wells that were constructed in 1961 (locations shown on Figure 2). Groundwater levels generally fluctuate about 30 feet annually. The high water level is about 10-20 feet below ground surface, with higher water levels closer to the creek or farther up the valley.

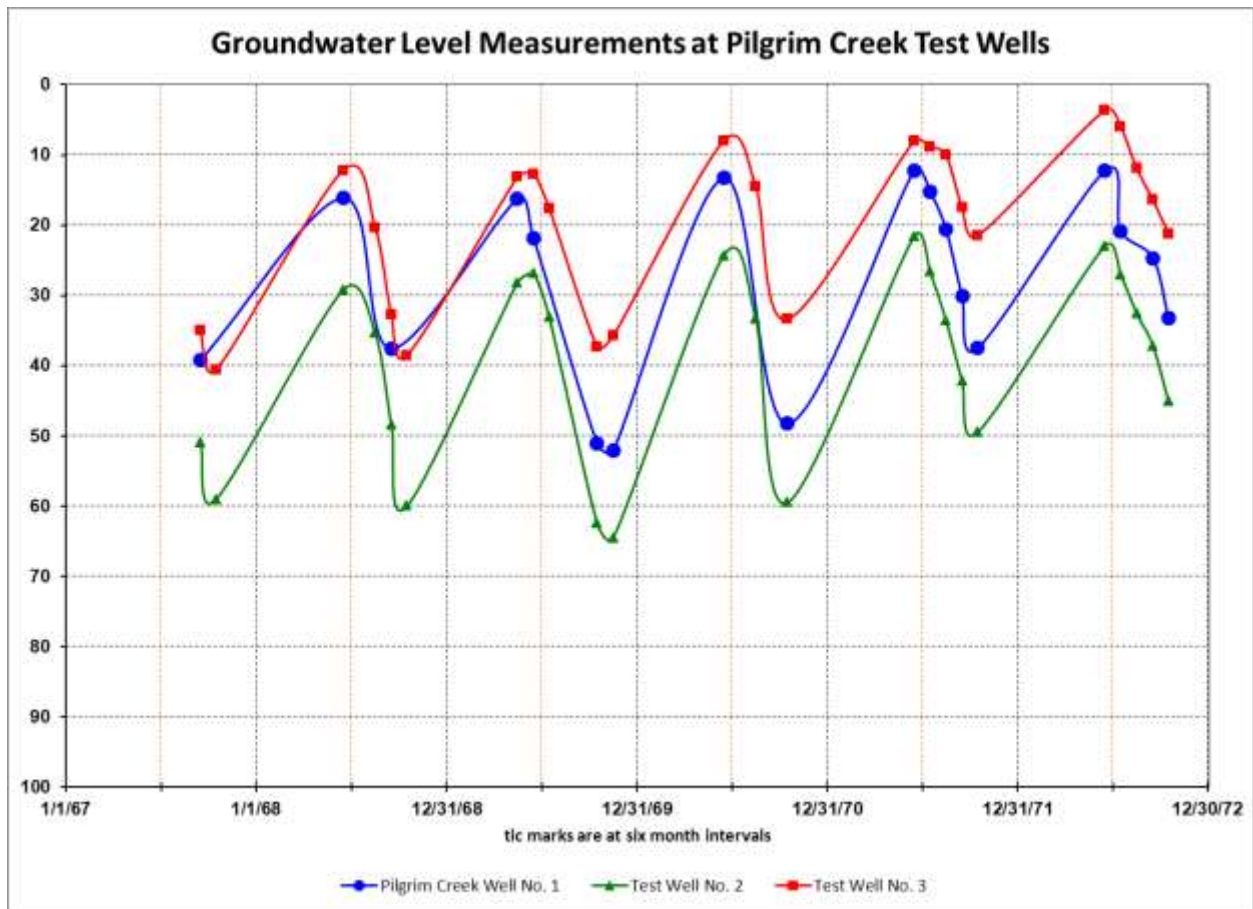


Figure 4. Groundwater levels at Pilgrim Creek Test Wells 1967-72.

Pilgrim Creek Public Water-Supply Wells

There are three public water-supply wells along Pilgrim Creek, upstream of the highway bridge (Figure 5).

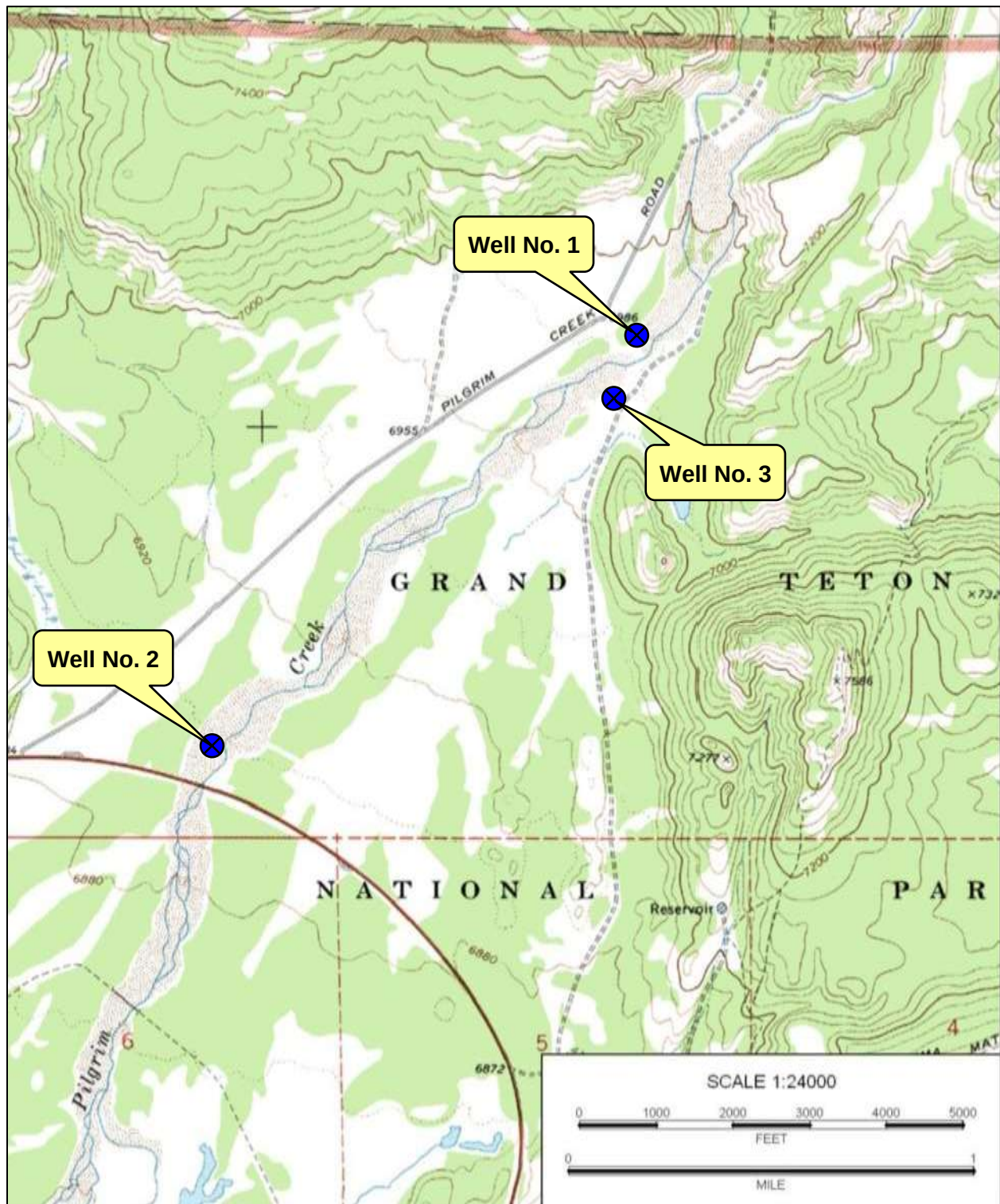


Figure 5. Locations of public water-supply wells along Pilgrim Creek.

Construction of a Pilgrim Creek Well No. 1 was started in August 1962. The well was not completed until the following summer, in July 1963. The well was drilled to a depth of 201 feet. It was completed with perforated steel casing from 69-134 feet below ground surface, corresponding with the gravelly layers in the alluvium. Below 140 feet, the well was drilled through fine sand. There was no attempt to develop water from the sand. The well was test pumped for 24 hours at 150 gpm, resulting in 0.1 foot of drawdown. The State Engineers Office permit number for the well is U.W. 842. Water from Well No. 1 is one of the two sources for facilities at Colter Bay. Water is pumped from Well No. 1 to facilities at Colter Bay for several months and then pumping is switched to Well No. 2.

Pilgrim Creek Well No. 2 was completed in October 1975. It was drilled to a depth of 175 feet and was completed by perforating the casing between 77-140 feet below ground surface, corresponding with the gravelly sediments encountered during drilling. The well was test pumped at 200 gpm for 4 hours, resulting in 3 feet of drawdown. The State Engineers Office permit number for the well is U.W. 30080. Water from Well No. 2 is one of the two sources for facilities at Colter Bay. Water is pumped from Well No. 2 to facilities at Colter Bay for several months and then pumping is switched to Well No. 1.

Pilgrim Creek Well No. 3 was completed in November 1985. It was drilled to a total depth of 250 feet and was completed by perforating the casing between 138-225 feet below ground surface, corresponding with the gravelly sediments encountered during drilling. The well was test pumped at 370 gpm for 25 hours, resulting in 6 feet of drawdown. There is no record of a permit for this well from the State Engineers Office. Pilgrim Creek Well No. 3 is the water supply for facilities at Jackson Lake Lodge.

Groundwater Level Measurements at Water-Supply Wells

Groundwater level measurements at the existing wells along Pilgrim Creek show that the depth to groundwater changes several tens of feet from spring to fall. The pattern of seasonal variation is very similar from one year to the next. Frequent measurements were made at Well No. 1 for the first 15 months after construction of the well. Cox (1974) made measurements at Wells No. 1, 2, and 3 approximately monthly from June to October from 1967-72 (discussed in a previous section of this report). USGS made measurements at Wells No. 1, 2, and 3 in early-June and early-September from 1989-95.

The graph of all of the groundwater level measurements at Well No. 1 (Figure 6) shows that the typical high water level is about 15 feet below ground surface. This is probably several feet lower than the bottom of the creek in this area, although we don't yet have good survey data to verify this presumption. The groundwater level is 40-50 feet below ground surface by late summer (September – October). Because the water table is far below the creek, drawdown of the water table from pumping of the well cannot affect the rate of infiltration from the stream. The rate of infiltration is controlled by the permeability of the sediments underlying the creek.

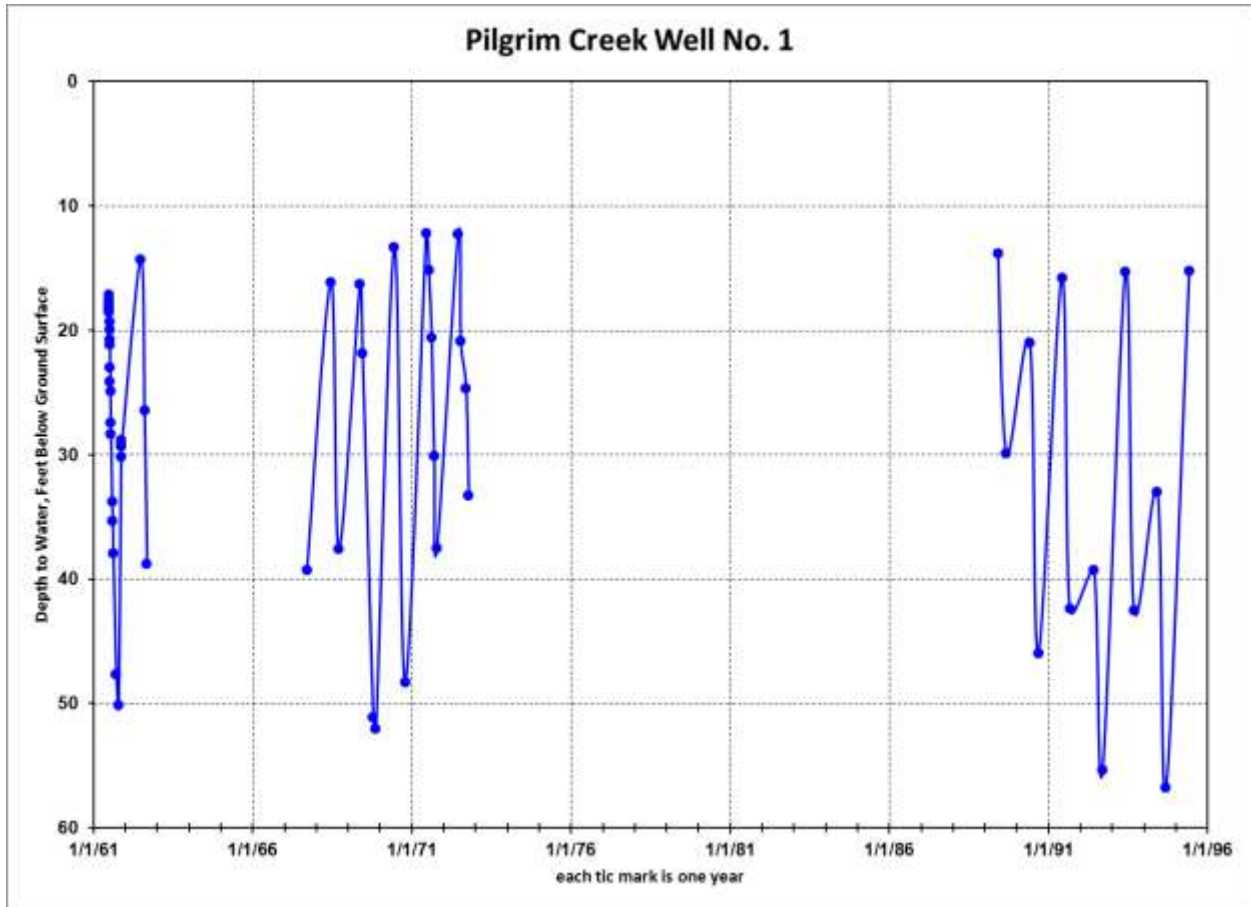


Figure 6. Groundwater level measurements at Pilgrim Creek Well No. 1.

The USGS measured depth to groundwater at the public water-supply wells at Pilgrim Creek from 1989-95 (Figure 7). The locations of these wells are shown on Figure 5. Groundwater levels were measured in early-June and early-September to provide an indication of the seasonal high water table and the depth to water at the end of the summer. Results are similar to what had been observed in previous monitoring; with about 20-30 feet of change from early to late summer.

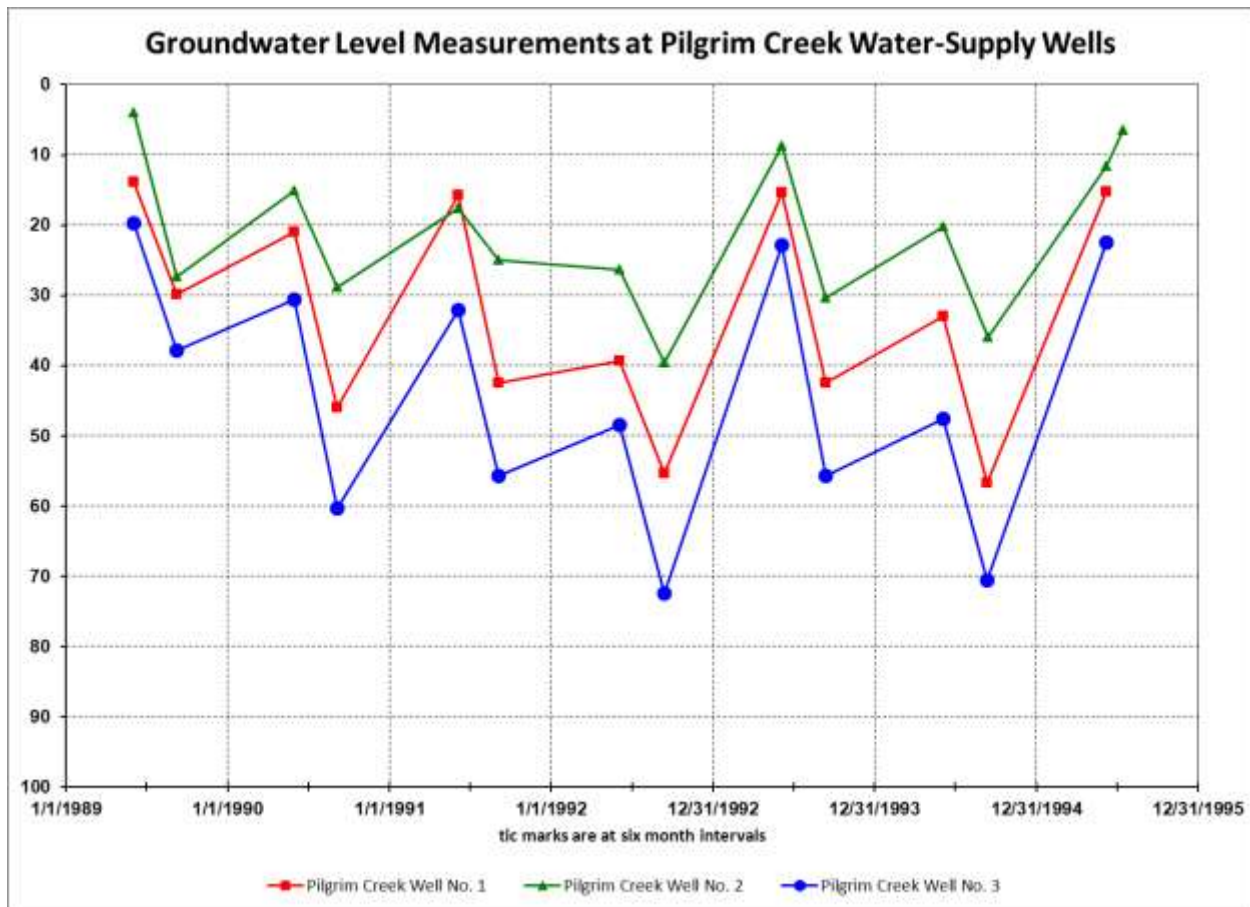


Figure 7. Groundwater levels at Pilgrim Creek Public Water-Supply Wells 1989-95.

Groundwater Pumping

Pilgrim Creek Well No. 3 supplies water to facilities at Jackson Lake Lodge. Pilgrim Creek Wells No. 1 and 2 supply water for facilities at Colter Bay. Pumping for facilities at Colter Bay alternates between Wells No. 1 and 2, typically pumping from each well for about 6 months before switching to the other.

Well pumping records for 2008-11 were obtained from park staff (Figure 8). Peak demand for the two water systems is around 500,000 gallons/day in July and August. Demand was slightly higher in 2011. Future data will reveal whether that is the start of a trend or an anomaly. It is useful to convert the average daily pumping data to cubic feet per second (ft^3/s) to compare it to streamflow in Pilgrim Creek. Peak groundwater pumping is about $0.75 \text{ ft}^3/\text{s}$. Streamflow during late July and August is receding, but remains about $20 \text{ ft}^3/\text{s}$ in the upper part of the valley. Groundwater pumping approaches about 5% of streamflow in late summer, but the water level data shows that the groundwater level is far below the creekbed at that time. Groundwater pumping cannot induce additional infiltration from the stream when the stream is perched above the water table.

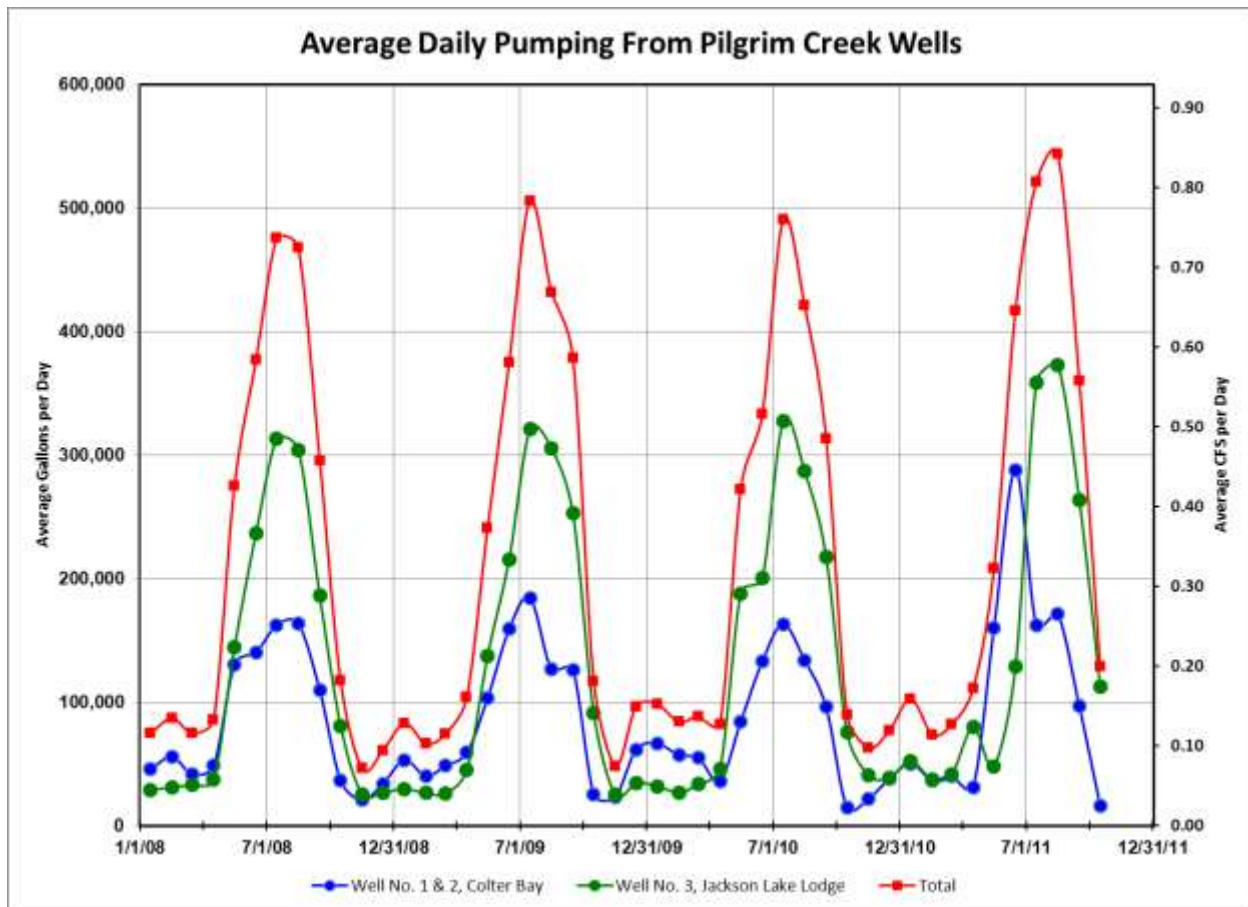


Figure 8. Groundwater pumping from wells at Pilgrim Creek.

Streamflow Measurements

USGS operated a streamflow gaging station at the Hwy 89/287 bridge during the summer of 1997 (Figure --). It is thought that the hydrograph has a shape that is typical of most years with high peak flows in May and June in response to snowmelt runoff. Streamflow recedes through the summer and achieves a baseflow of around 20 ft³/s through the remainder of the year. Peak flow in 1997 was higher than normal, hydrologic analysis of the discharge data indicated that the peak flow was near the 100-year flood peak

(www.usbr.gov/pmts/sediment/projects/PilgrimCreek/PilgrimCreek.htm)

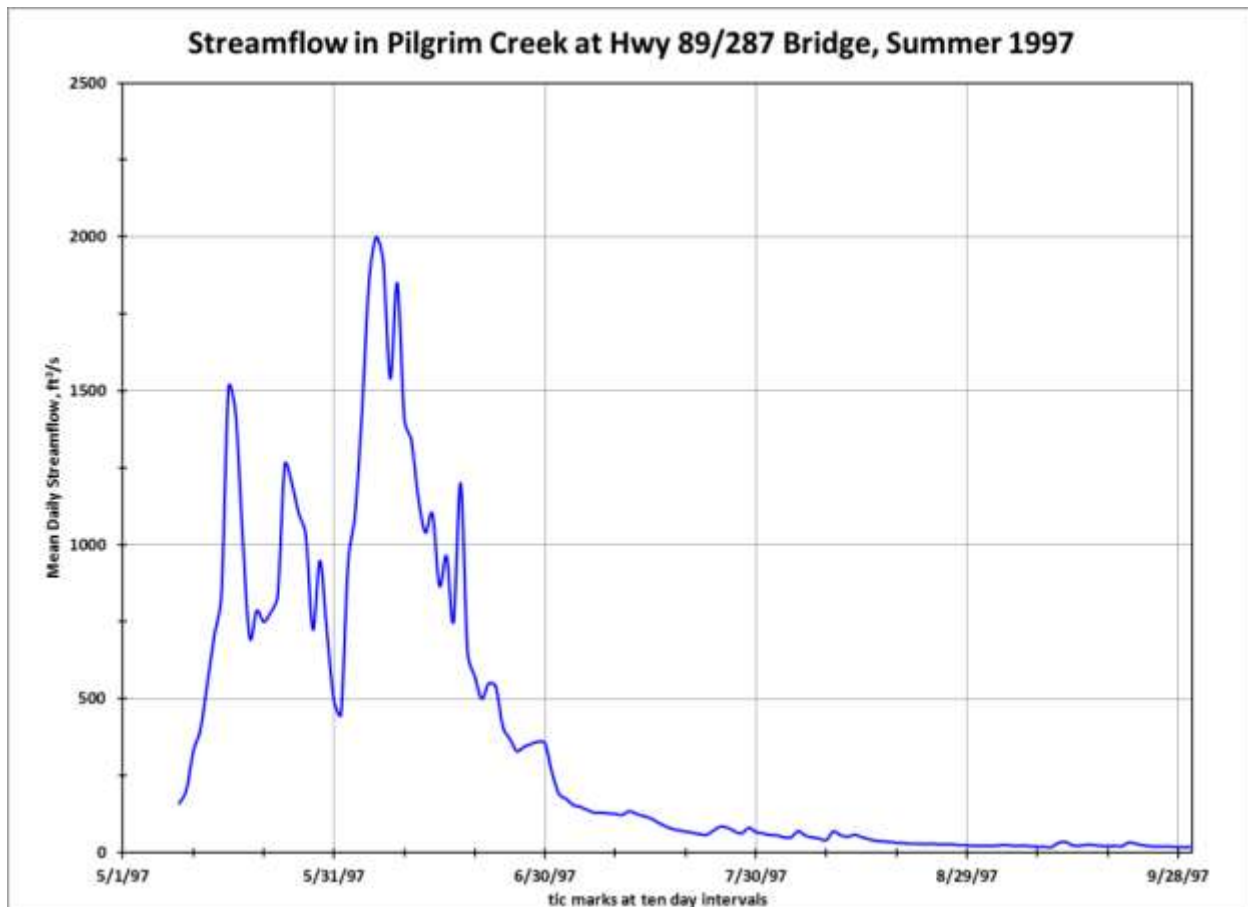


Figure 9. Mean daily streamflow at the Hwy 89-285 bridge, 1997.

Streamflow Gains/Losses

North of the park boundary both forks of Pilgrim Creek flow on bedrock in narrow mountain valleys. Below the confluence, Pilgrim Creek flows across a thick layer of glacial sediments (predominantly outwash) filling an area that was scoured by glaciers. Most of the recharge to the alluvial aquifer is seepage from Pilgrim Creek. Above the confluence of the forks of Pilgrim Creek, where the stream flows across bedrock, infiltration is minimal and streamflow is perennial. Downstream of the confluence, where the stream flows across alluvial sediments, the infiltration rate is large and streamflow decreases downstream, often disappearing completely for a reach in the vicinity of the old and new highway bridges.

Streamflow measurements have been made at miscellaneous sites on Pilgrim Creek (Figure 10) at various times. In some cases, these measurements were made at upstream/downstream locations on the same date to provide a measure of the seepage loss/gain of the creek.

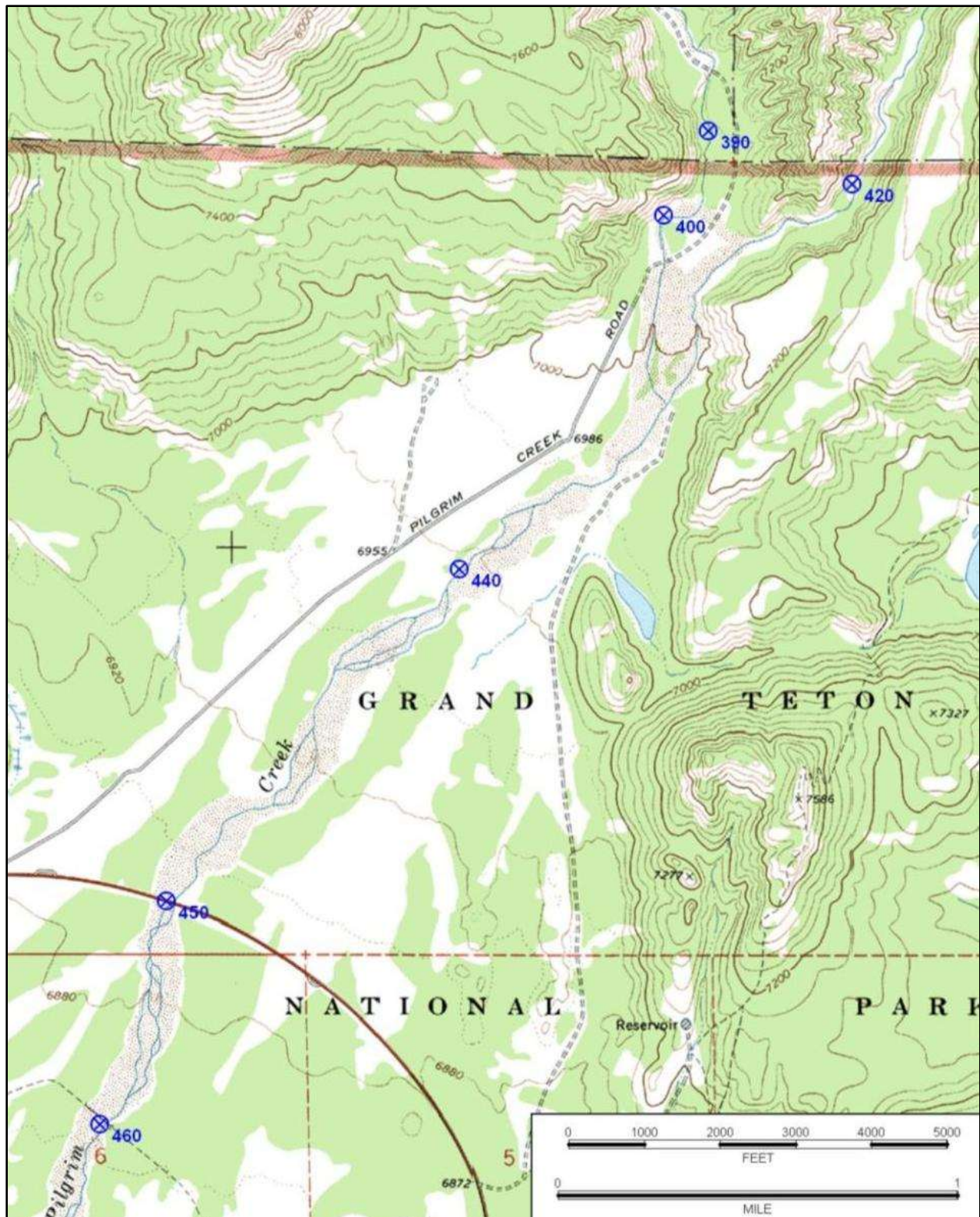


Figure 10. Locations of USGS streamflow gaging stations on Pilgrim Creek.
All station numbers are preceded by 13010, e.g., the complete station number at the Hwy 89/287 bridge is 13010450.

USGS personnel measured flow in Pilgrim Creek on June 17, 1960. Streamflow was 197 cfs at a point about 0.85 mile downstream from the confluence of the forks of the creek (Station 440, Figure 3). Streamflow was 176 cfs at a point about 2½ miles downstream from the confluence, 300 feet downstream from the old highway bridge (Station 460, Figure 3). These measurements show a loss of 21 cfs, or 14 million gallons per day, over a reach of 9,000 feet (McGreevy and Gordon, 1964). The amount of water lost to evaporation and transpiration over this reach is miniscule compared to the amount lost to infiltration into the alluvial aquifer.

USGS conducted several paired measurements during low-flow on Pilgrim Creek in 1969-72. Most of the measurements were made between Station 440 and a site about 1000 feet upstream from the highway bridge. Over this reach of about 5000 feet, the measured streamflow loss was 2.6 cfs on Sept. 25, 1969; 4.3 cfs on Aug. 17, 1971; 2.3 cfs on Sept. 20, 1971; 8.8 cfs on July 26, 1972; and 4.0 cfs on Sept. 21, 1972. (Cox, 1974)

Date	Streamflow (ft ³ /s) Upstream site	Streamflow (ft ³ /s) Downstream site	Streamflow Loss (ft ³ /s)
9-25-69	17.2	14.6	2.6
8-17-71	24.8	20.5	4.3
9-20-71	15.9	13.6	2.3
7-26-72	48.1	39.3	8.8
9-21-72	14.1	10.1	4.0

Additionally, the measured streamflow loss between the confluence of the forks of Pilgrim Creek and Station 440 (a linear distance of about 5000 feet) was 7.5 cfs on Sept. 21, 1972. The measured loss between the new highway bridge and the old highway bridge (linear distance of about 3000 feet) was 4.8 cfs on Sept. 20, 1971.

These data show that a streamflow loss of 1 cfs per 1000 feet is not unusual for Pilgrim Creek as it flows across the alluvial fan. (Cox, 1974)

Clark, et.al. (2004) conducted streamflow gaging on Pilgrim Creek as part of an assessment of water quality characteristics of tributaries to the Snake River. The upstream site for streamflow measurements was just below the confluence of the East and West Forks of Pilgrim Creek. The downstream site was at the Hwy 89/287 bridge. The distance between the two sites is about 2 miles. Streamflow loss between the upstream and downstream sites ranged from 27 ft³/s on June 11, 2002 (high flow) to 6 ft³/s on September 16, 2002 (low flow). These data are consistent with previous measurements showing streamflow loss of about 1 ft³/s per 1000 feet of stream.

Date	Streamflow (ft ³ /s) Upstream site	Streamflow (ft ³ /s) Downstream site	Streamflow Loss (ft ³ /s)
6-11-02	225	198	27
7-22-02	34	27	7
9-16-02	16	10	6
11-05-02	11	2.2	8.8

GRTE staff made streamflow measurements of Pilgrim Creek on August 17, 2010 (personal communication, Chad Whaley). The first measurement was about 25 meters below the confluence of the forks of Pilgrim Creek. Subsequent measurements were made about 1000 and 2000 meters downstream of the forks. Streamflow at the confluence was 19.1 ft³/s; 1000 meters downstream the flow was 18.6 ft³/s and 2000 meters downstream the flow was 7.3 ft³/s. At a fourth site, approximately 1000 meters further downstream, no measurement could be made because the stream was dry.

Observations of Dry Reaches

In the summer of 2010, GRTE staff made observations of the extent of flowing vs. dry reaches of Pilgrim Creek for low-flow conditions (Personal communication, Chad Whaley). Observations were made on August 9, 17, 19, and October 6 (Figure 11).

On August 9, 2010, the creek was observed to go completely dry about 400 meters downstream of the Hwy 89/287 bridge. There was continuous flow in the creek for about 4600 meters below the confluence. The streambed remained dry for about 1200 meters before water began to emerge from the substrate. Intermittent pools were observed for the next 400 meters before continuous flow was restored. From this point, flow was continuous to Jackson Lake.

On August 17, the stream was observed to go dry about 700 meters upstream of the Hwy 89/287 bridge. There is no mention of where streamflow reemerged downstream.

On August 19, the stream was observed to go dry 600 meters further downstream than it had on August 17, two days earlier. There had been no rain between the 17th and 19th, so it was quite unexpected to find the stream reemerging several hundred meters further downstream.

Streamflow conditions were again observed on two occasions in October. On October 6, the creek went dry under the Hwy 89/287 bridge, with some disconnected pools extending 20 meters downstream from the bridge. Streamflow reemerged at the same location as was observed on August 19. On October 20, flow was observed to continue under the bridge with only a couple of cfs.

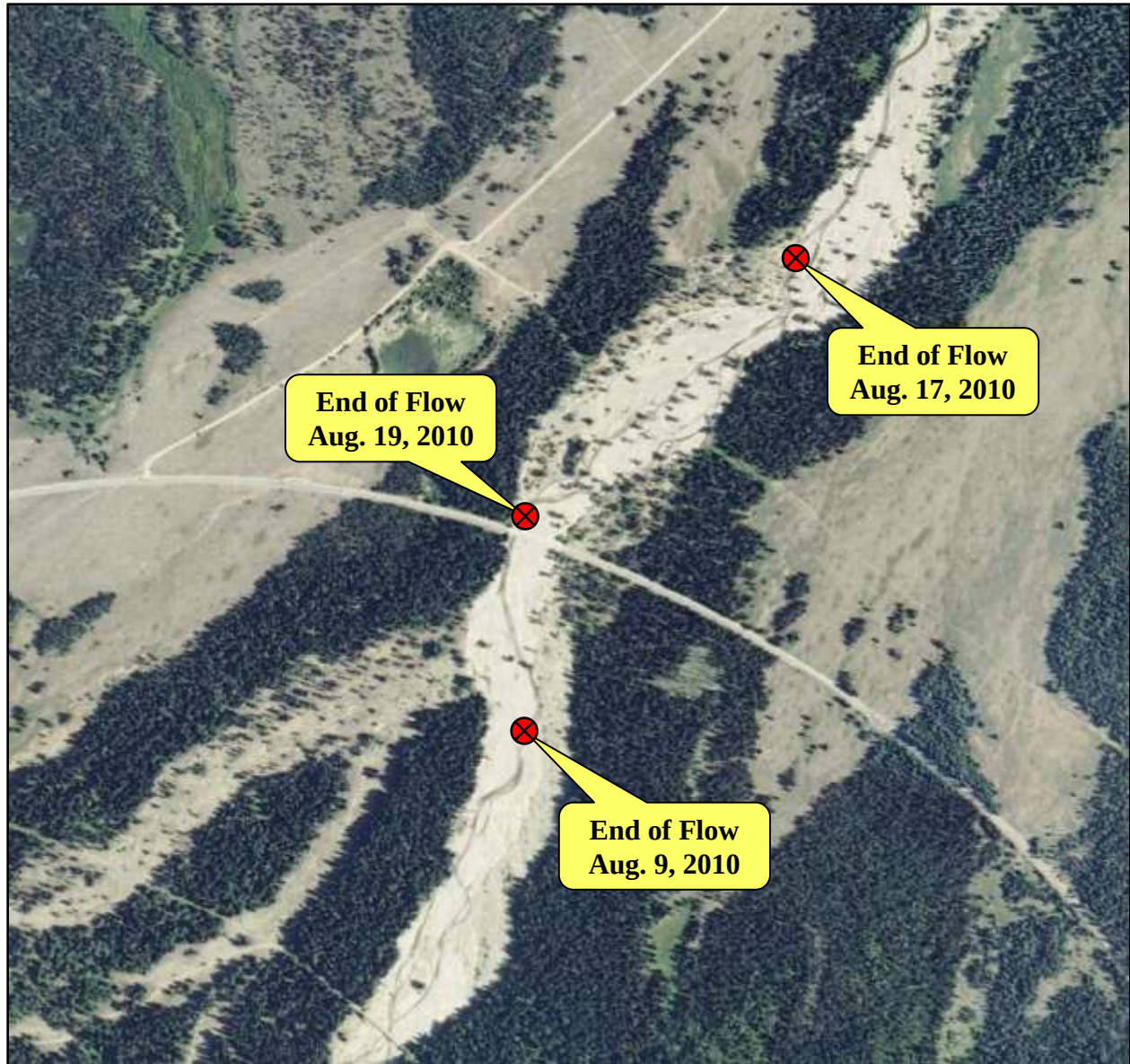


Figure 11. Extent of streamflow for various dates in 2010.

A limited number of observations in 2010 showed that the extent of streamflow and dry reaches in Pilgrim Creek is highly variable. The observed extent of wetted areas did not follow an intuitive pattern. For example, continuous streamflow on August 19 extended 600 meters farther downstream than on August 17, even though there had been no rainfall during that period.

Re-emergence of Streamflow in the Lower Reach of Pilgrim Creek

In the lower part of the valley, below the old highway bridge, the water table rises to intersect the land surface and groundwater discharges into the creek, other small streams, and wetland areas. The most probable explanation for the emergence of groundwater to the surface is that the

permeability of the alluvial sediments decreases toward the downstream toe of the fan. The finer-grained sediments that were carried farther downstream settle out as the gradient and flow rate decreases. Because the permeability is lower, groundwater flow through the sediments is slower and some of the groundwater is forced to the surface.

Several short streams occur on the lower part of the alluvial fan. Water in these creeks likely comes from the alluvial fan as water that infiltrated into the upper part of the fan (and flowed downstream as groundwater or underflow) exits to the surface as it encounters fine-grained, less permeable sediment in the lower part of the fan. Spring Creek, Half Creek, First Creek, and Second Creek are all examples of these short streams on the toe of the fan. [Diking and manipulation of Pilgrim Creek to direct flow toward the west, away from the Jackson Lake Dam, has caused the flow of Pilgrim Creek to be routed down the channel of Second Creek.]

Drought Indices

The hydrological impacts of drought (e.g., reservoir levels, groundwater levels, etc.) take longer to develop and it takes longer to recover from them. The *Palmer Hydrological Drought Index (PHDI)*, another long-term drought index, was developed to quantify these hydrological effects. The PHDI responds more slowly to changing conditions than the more commonly used *Palmer Drought Severity Index (PDSI)*.

The PHDI for the Snake River drainage basin in Wyoming is shown in Figure 12. Positive numbers (above the red line) are periods of wetter than normal conditions. Negative numbers (below the red line) are drought periods. The graph shows that the area was much wetter than normal from 1995-2000. Streamflow during this period would likely have been higher than normal and was probably more continuous. This was followed by a 4-5 year drought. Streamflow during this period would likely have been less than normal and there would be more occurrences and longer extent of dry reaches in the creek. Climate conditions from 2004-2010 alternated between shorter periods of wetter than normal and drought.

Persons who have been at the park for the past 20 years are likely to recall the wetter than normal conditions of the 1990s as “normal” because that’s the way they saw it for several years. They may then have observed the drastic difference of streamflow during the severe drought from 2000-04. Current conditions of alternating wet and dry years and the associated effects on streamflow may be more the normal condition for this stream. Periods of no flow in Pilgrim Creek may be especially noticeable because the main highway through the park crosses the creek and it’s readily observed when there is a wide gravel streambed with no water to be seen.

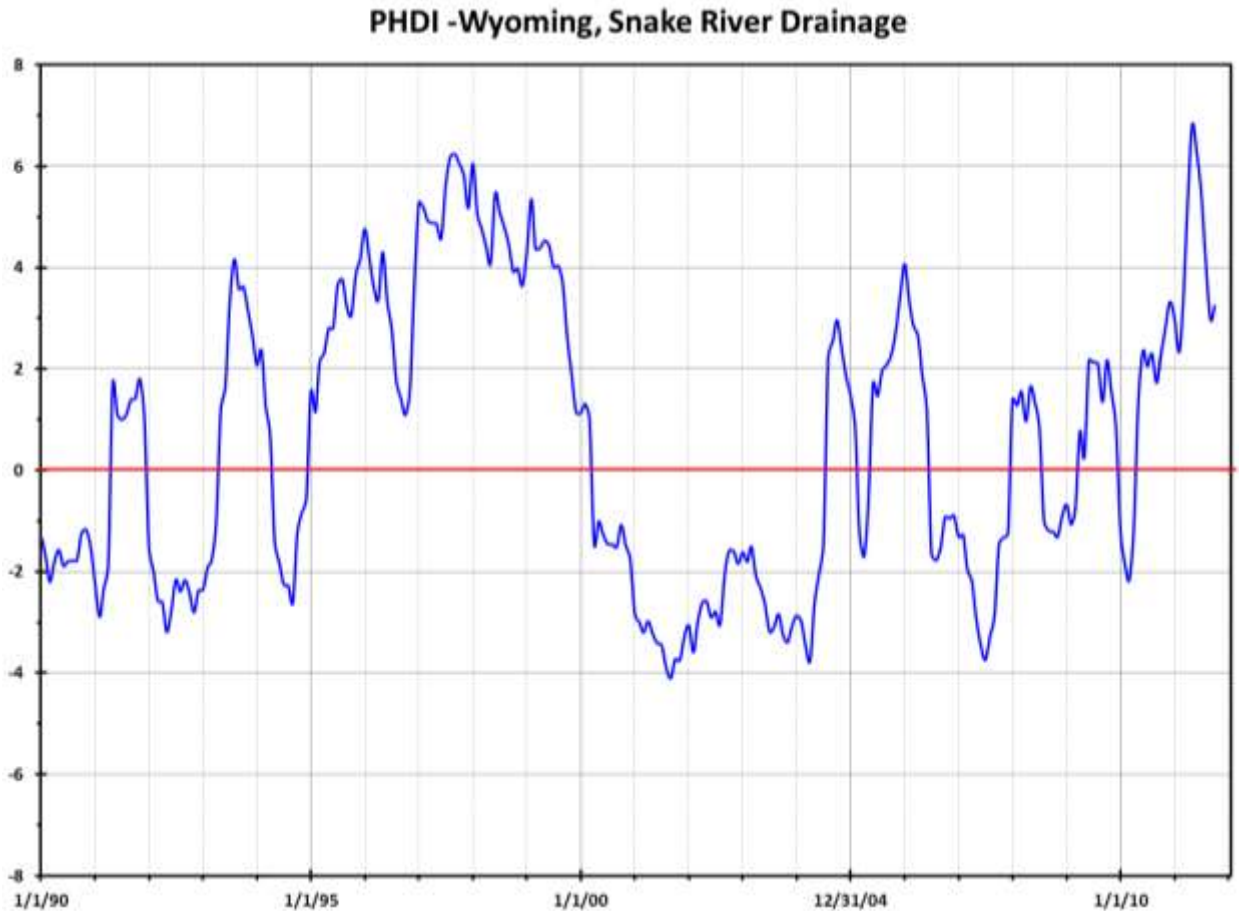


Figure 12. Graph of Palmer Hydrological Drought Index for the Snake River drainage basin area.

Manipulation of the Channel of Pilgrim Creek

The upper parts of the Pilgrim Creek drainage basin is in steep forested canyons where the creek flows on bedrock. The lower portion of the Pilgrim Creek (approximately 5 miles) flows across an alluvial fan before entering Jackson Lake. The southern portion of this fan is called Willow Flats. This area has a high water table and dense stands of willow. The north embankment of the Jackson Lake Dam is on the Willow Flats portion of the alluvial fan.

Because there was some perception that the channel of Pilgrim Creek might migrate toward, and endanger the stability of, the Jackson Lake Dam, the lower part of the Pilgrim Creek channel has been the focus of repeated efforts by the Bureau of Reclamation to direct this part of the creek to the west, away from the dam. The cumulative result of these efforts (which began in 1941) is that the lower two miles of the historical creek channel have been abandoned and Pilgrim Creek has been forced into the channel of Second Creek, almost a mile west of the original channel and the dam. The redirection of the creek was accomplished by digging channels and constructing dikes. These activities continued until 1997 (possibly longer). Figure 13.

Diversion of Pilgrim Creek into the Second Creek drainage was begun in 1975. Incision of the channel into the fan surface along the entire lower channel section had been completed by about

1979. Subsequently, the channel has been progressively widening to accommodate the larger volumes of flow in the active channel. The geometry of the channel has changed as the area has gone through drought and wet periods and the channel adjusts to different volumes of streamflow while adjusting to a new state of equilibrium.

A large delta has formed at the mouth of Pilgrim Creek (and now Second Creek also) where they flow into Jackson Lake. The slope of the creek decreases rapidly as it encounters the slack water of the lake. Channel deposits occur as laterally discontinuous sand bars which extend about a half mile upstream from the mouth of the creek. Lowering of water level in the reservoir during late summer and early fall causes erosion and flushing of the delta deposits and sand bars further out into Jackson Lake. Deposition of coarse sand to fine gravel occurs in the channels during this period. This process of alternating delta and channel deposition occurs on an annual basis, resulting in interbedded and interfingering deposits in the lower end of the creek.

A series of wetter than normal years might result in less drawdown of the reservoir and therefore less erosion of sediments from the lower end of the creek into the reservoir. Conversely, a series of dry years might result in longer and larger drawdown of the reservoir, resulting in more erosion from the lower reaches of the creek. It would be difficult to compare conditions from one year to the next or across a series of years because of the ever-changing hydrologic conditions.

The upper parts of the drainage basins of Pilgrim Creek and the East Fork are the sources of the sediment on the alluvial fan and in the stream channel. Periodic reactivation of landslides or wildfires in the upper basins can temporarily increase the sediment yield for a few years, creating another disturbance to “equilibrium” conditions for streamflow and channel geometry.

The stream channel on the lower part of the fan continues to adjust to recent human disturbances on the fan. These responses will continue as the channel adjusts toward a new equilibrium condition. Incision of the creek into the lower part of the fan occurred fairly quickly following the major diversion of Pilgrim Creek into the channel of Second Creek. Widening of the channel to accommodate high flows has been a slower process, impeded by several years of drought and low streamflow. Under more normal runoff and streamflow conditions, there has been widespread lateral bank erosion on the lower fan. Lateral erosion is expected to continue until the channel has attained a width capable of passing the normal high flows. Not all of the sediment eroded during this channel widening process is transported to the lake. Some of the sediment is deposited in the lower reach of the channel, resulting in aggrading conditions, i.e., the channel on the lower part of the fan is getting wider but shallower.

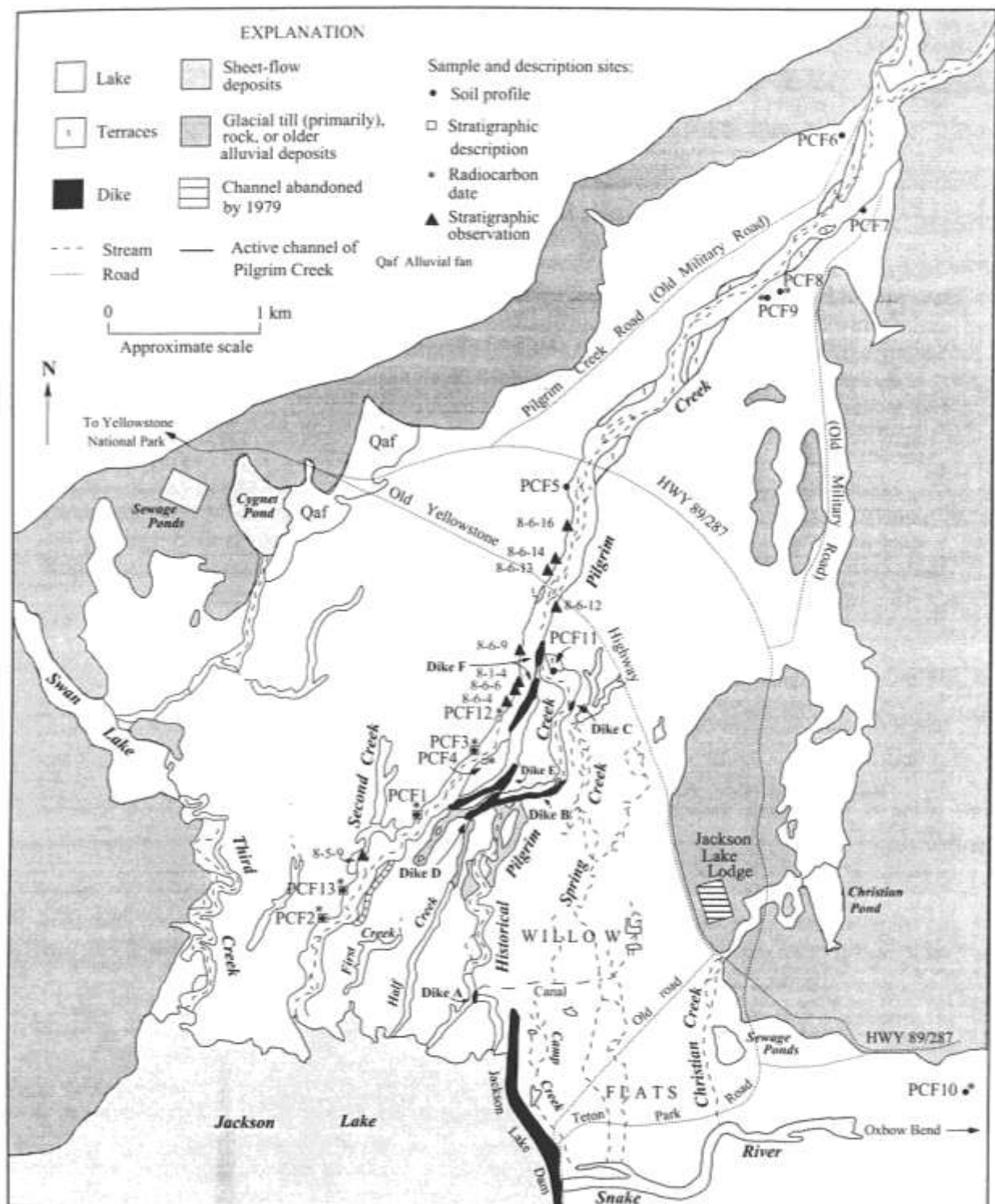


Figure 13. Sketch map of the Pilgrim Creek alluvial fan showing the major physiographic and geologic features, dikes that were constructed by the Bureau of Reclamation, and former channels of Pilgrim Creek. Source; Bureau of Reclamation (1998).

Conclusions

- Pilgrim Creek loses a lot of water as it flows across the alluvial fan. The loss is especially great from the confluence of the east and west forks to below the Hwy 89/285 bridge.
- A large reach of the stream goes dry most years. The dry reach generally extends a few thousand feet upstream and downstream of the bridge. The extent of the dry reach varies from year-to-year, depending on climatic variability.
- Groundwater pumping from the water-supply wells does not affect streamflow in Pilgrim Creek as the creek is perched above the water table most of the time in the vicinity of the wells.

Recommendations

There are opportunities for low-level of effort, opportunistic monitoring to verify the conclusions presented in this report and to document the frequency and extent of dry reaches in Pilgrim Creek. Construction of a new water-supply well is planned in the next few years to move the existing Well No. 1 and the chlorination building out of the floodplain. The existing well might then be converted to use as a monitoring well at essentially no cost. An additional monitoring well, or two, might be constructed near Pilgrim Creek to further define the natural fluctuation of the water table and effects of groundwater pumping.

- Document the extent of streamflow, dry reaches, and re-emergence of the streamflow in August-October; similar to the monitoring that was conducted in 2010. This monitoring might be done at 2-3 week intervals.
- In conjunction with monitoring the extent of streamflow, make streamflow measurements at the confluence and 1-2 sites downstream to document the rate of loss during low-flow conditions.
- Monitor groundwater levels at existing wells and compare to the elevation of the creekbed to verify that the stream is perched above the water table or to document the period when it is perched or when the groundwater and surface water are interconnected.

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