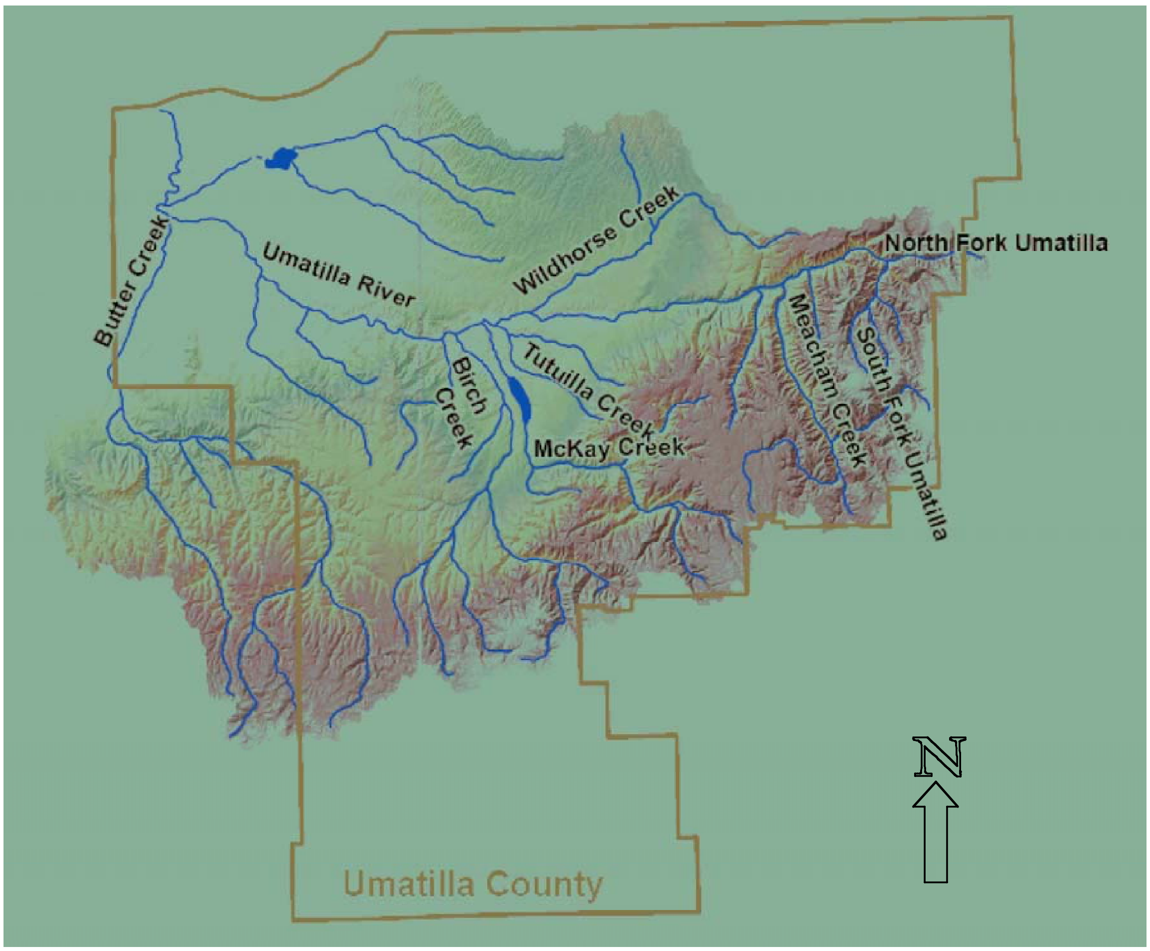
Umatilla Sub-Basin Data Synthesis and Summary

Prepared by the
Institute for Water and Watersheds
at Oregon State University



For the
Umatilla County Critical Groundwater Task Force
and the Stakeholders of Umatilla County
July 4, 2006

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Introduction

The Institute for Water and Watersheds at Oregon State University has prepared this document for the Umatilla Country Critical Groundwater Task Force. The project was designed as an experiment to determine if water resource information was readily-available and easily compiled by a citizen who does not have technical background in water resources engineering or science. For the purpose of this project, two graduate students at Oregon State University were tasked with (1) compiling a data synthesis based on an outline of information requested by the Task Force (see Appendix A) and (2) updating water level maps of the basalt aquifers that were reported by the Oregon Water Resources Department (OWRD) in the 1980's.[1] The purpose is to summarize the most relevant available information about the water resources of the Umatilla Basin to support on-going water planning efforts.

Declining groundwater levels in wells tapping the deep basalt aquifers in many areas of the Umatilla Basin indicate the balance between annual recharge and the natural discharge to surface water has been disrupted by groundwater pumping, on the basis of a literature review compiled by Kennedy and Jenkins for the Task Force 2005.[2] The current data available relating to water resources in the Umatilla Basin includes more than 220 published documents, multiple websites containing water quality and quantity data, water rights data in raw form, multiple unpublished (draft) documents, and other documents that are not widely distributed (i.e. municipal water conservation plans, private water consumption data). This is an attempt to distill massive amount of information into a readily useable format for those who need to make water management plans and decisions, including members of the Umatilla County Critical Groundwater Taskforce and the stakeholders of Umatilla County.

This report is divided into two main sections. The first section introduces basic water resource concepts. The second section is the actual "Data Synthesis." It is the goal of the authors to present the available information in a way that accurately depicts the current and forecasted water resources in the Basin. It will focus on the area of the Umatilla Basin that is contained strictly within Umatilla County. This area includes most of Umatilla County (note the geographic on the cover), with the exception of the northeastern part of the County which is located within the Walla Walla River Basin, and the portion in the southern end of the County that is located within the John Day River Basin. Thus the Task Force may find it valuable to include analysis these adjacent Basins in effort to develop a more comprehensive understanding of the surface and groundwater features that affect Umatilla County.

Overview

What actually constitutes the "Umatilla Basin" is a confusing issue and depends on the emphasis of the data collection or the policy. As the reader will notice in subsequent

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[1] OWRD, 2003
[2] Kennedy & Jenks, 2005

sections, the geographic outline of the "Umatilla Basin" varies by the study. Thus for the purposes of this report, the focus is on the Umatilla River Basin.

The Umatilla River Basin covers an area of about 2,545 square miles. It is a drainage basin, which means that a drop of water falling anywhere within these boundaries could (theoretically) drain out into the Columbia River through the mouth of the Umatilla River. The Umatilla River originates on the well-watered slopes of the Blue Mountains, and flows about 90-miles in a generally westward direction over part of the much drier Columbia plateau and into the Columbia River. The main stem Umatilla River begins at the confluence of the North and South Forks, 90-miles from the mouth, or outlet. It has eight major tributaries: The North and South Forks of the Umatilla River and Meacham Creek in the upper Basin; Wildhorse, Tutuilla, McKay and Birch Creeks in the mid-Basin; and Butter Creek in the lower Basin as seen on the cover map.

Climate

The climate of the entire basin is not easily characterized. It ranges from particularly warm and dry in the lower basin (closest to the Columbia River), to relatively cool and wet in the Blue Mountains. The average annual precipitation near Umatilla and Hermiston is about 9-inches per year, increasing to about 12-inches per year at Pendleton, to as much as 50-inches of annual precipitation in the highest elevations of the Basin.[3]

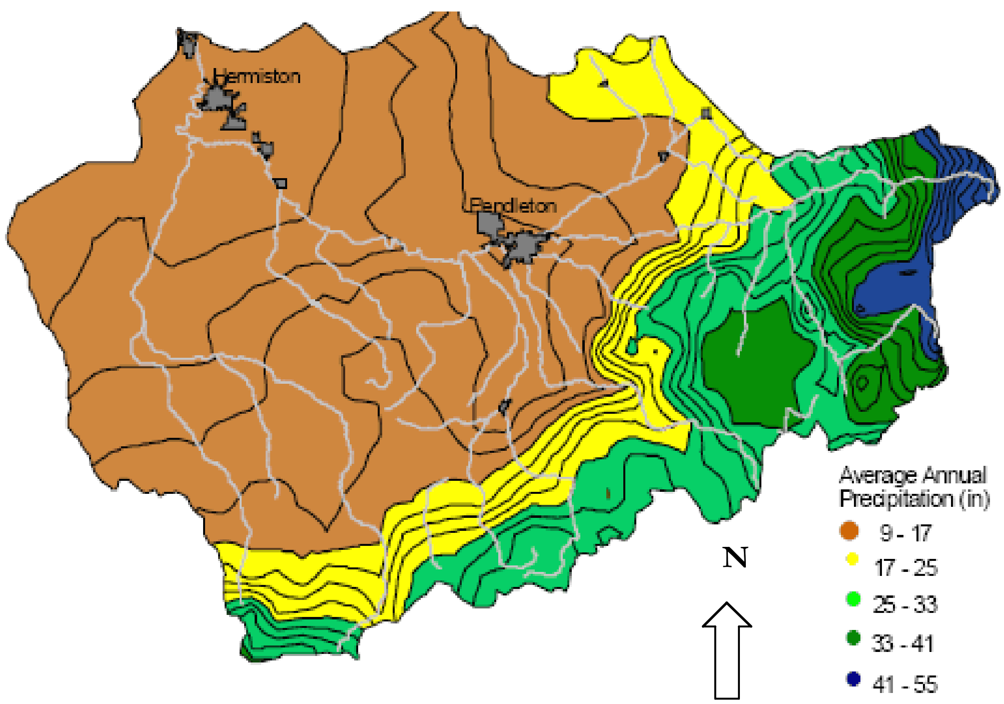

Figure 1: Average annual precipitation in the Umatilla Basin using 2-inch contour intervals (ODEQ, 2001)

[3] Taylor et al., 1999

The Oregon Climate Service has prepared a Special Report on the climate of Umatilla County dated February 2005.[4] In winter months, the average temperatures at Hermiston, Pendleton and Meacham are 35, 36 and 29°F respectively.[5] In summer months, the average temperature is 60°F at Meacham and 71°F at both Hermiston and Pendleton.[5] The growing season, based on the number of days 32°F and above is an average of 173-days near Hermiston, , and 188-days near Pendleton.[3] Summer thunderstorms occasionally bring localized downpours, but the bulk of the annual precipitation accumulates in the Blue Mountains during the winter months as snow.

The world's leading climate scientists are in general agreement that the onset global warming will lead to climate change. While there is some debate on how climate change will manifest itself globally and regionally, there is little doubt that water managers will experience complex and difficult challenges associated with climate change in the future. A synthesis of how climate change may regionally affect the hydrologic cycle in the Pacific Northwest in the following points.[6]

- Warmer temperatures will lead to a more vigorous hydrologic cycle; which for this region may translate to more severe droughts and flooding.
- Many models predict an increase in precipitation intensity and more extreme rainfall events.
- Summer rainfall may decrease.
- Evapotranspiration models are a little less reliable and there is uncertainty how vegetation will acclimatize to increasing atmospheric CO_2. However water loss to evapotranspiration is likely to be more dramatic with the onset of longer, drier summers.
- An overall decrease in soil-moisture is anticipated as any changes to the climate and evapotranspiration regime will affect soil-moisture and groundwater dynamics. Several factors contribute to this estimate, i.e. greater runoff potential associated with extreme rainfall events (less infiltration); the increase in population results in further urban development and this tends to produce higher runoff (less infiltration); longer, drier summers (higher evapotranspiration and evaporation), etc.
- Changes in snowfall and snowmelt can have dramatic changes to the hydrologic cycle. Predictions suggest that less precipitation will be in the form of snowfall, that the duration of the snowfall season will decrease, a decline in snowpack in the mountains, and earlier peak runoff - thus ending earlier in the spring. The outcome of this prediction is greater runoff, less natural recharge of the aquifers, and more intense drying of the soil during the summer months.
- Applying the discussion above it is reasonable to expect dramatic fluctuations between more severe flood and drought events. Both chronic water shortages associated with droughts and longer dry seasons; and flood associated damages to property and public infrastructure such as dams & levees, and degradation of soil quality due to erosion and runoff.

[4] http://www.ocs.orst.edu/county_climate/Umatilla_files/Umatilla.html
[5] ODEQ, 2001; SCS, 1988
[6] Gleick, 1998

Population

According to the U.S. Census Bureau, the 2005 estimated population of Umatilla County was 73,878-people.[7] The population density of Umatilla County is about 22-people per square mile. This figure confirms what one might assume from a drive around the Basin - the population density here is lower than the State average of about 32-people per square mile.[7]

According to the long-term County population forecast by the Oregon Office of Economic Analysis, the population of Umatilla County is expected to grow to more than 106,000-people by the year 2040.[8] If this estimate were realized, the population of Umatilla County would grow about 43% over a 35-year period. Because groundwater is used as the principal sources of drinking water, and industrial supply and as a supplemental source of irrigation water in the Umatilla Basin, there is a strong relationship between increases in population, increases in irrigated acreage, and increases in the depth to groundwater since 1950.

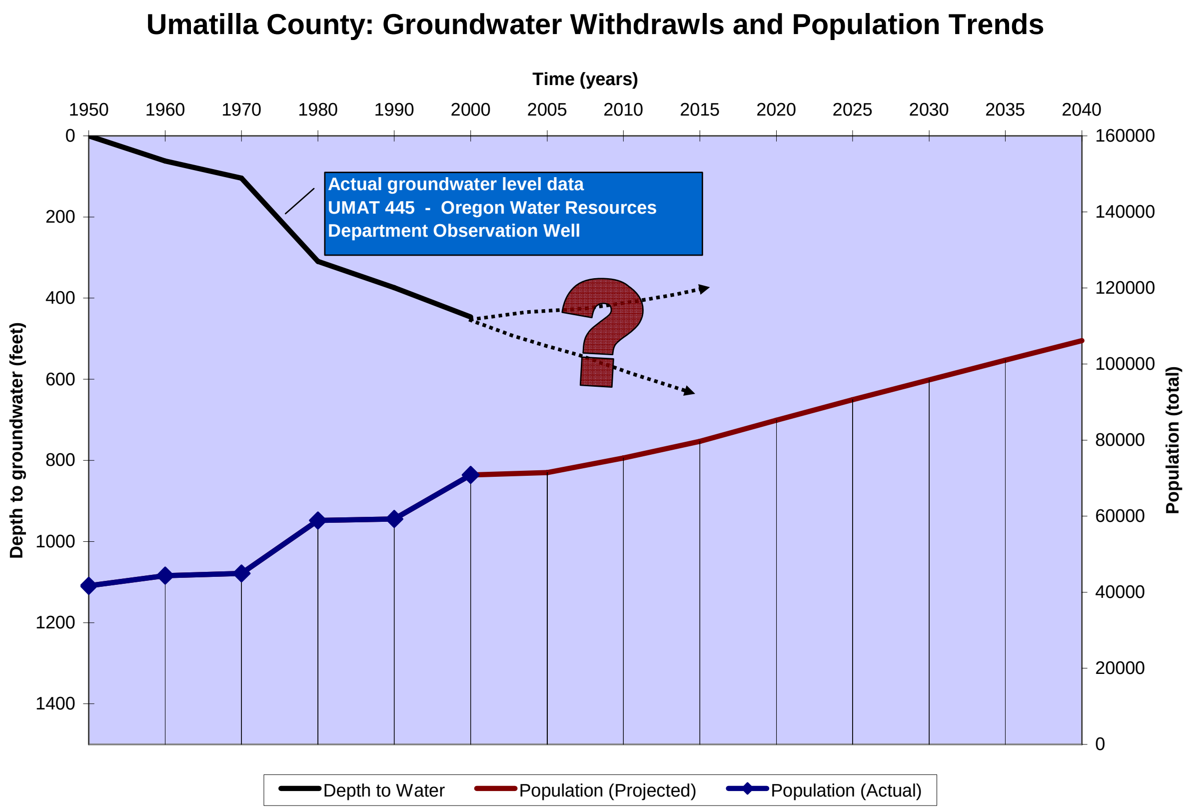

Figure 2: Irrigation, Domestic and Industrial use of groundwater increases as the population of Umatilla County increases. What does the future hold?

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[7] USCB, 2006
[8] OOEA, 2006

Land Ownership

83% of the land in the Basin is privately owned, a figure above average in the State of Oregon, which is 52.4% public lands.[9] The Federal government manages about 13% of the land in the Basin, and the Confederated Tribes of the Umatilla Indian Reservation comprises between 4 to 11.5% (depending on the reference) of the Basin.[10] Regarding land cover, about 19% of the land in the Basin is forested, 39% is or was used for farming, and about 40% of the land in the Basin is uncultivated shrub land that may be used for grazing.[10]

Land Cover/ Land Use in the Umatilla River Basin	Ownership						Totals	%
	Public		Private		Umatilla Indian Reservation			
	Acres	%	Acres	%	Acres	%		
Forest	131,600	8%	145,400	9%	22,100	1%	299,100	19%
Grain Crops	-	*	360,100	22%	18,300	1%	378,600	23%
Conservation Reserve Program Land	-	*	111,800	7%	-	*	15,700	7%
Grass/Pasture/Hay	-	*	140,000	9%	-	*	149,900	9%
Orchards/Vineyards	0	0%	-	*	0	0%	-	*
Row Crops	0	0%	-	*	0	0%	0	0%
Shrub/Rangelands	57,000	4%	566,500	35%	20,900	1%	644,400	40%
Water/ Wetlands/Developed/Barren	-	*	21,600	1%	-	*	25,400	2%
TOTAL	198,900	13%	1,345,900	83%	68,800	4 to 11%	1,613,600	100%
All values transcribed from similar chart in "Umatilla – 17070103, 8-digit Hydrologic Unit Profile", produced by the USDA NRCS Water Resources Planning Team, Portland, OR, August 2005.								

Figure 3: Land and Land Cover Use. A HUC is a "Hydrologic Unit Code", a number assigned to a drainage basin by USGS. In the Umatilla Basin, the majority of the land surface is undeveloped shrub or rangelands, and most of the land in the Umatilla Basin is privately owned. The percentage of ownership of lands on the Umatilla Basin is variable in this table because of an apparent overlap of public lands.

It may be worthwhile to further evaluate where these crops are grown, details of crop rotation, and details of the irrigation associated with each within the Basin. For example in the north County corn, onions, potatoes, peas, wheat, and alfalfa are grown. Additionally, it may be worth differentiating between irrigated poplars and natural forest acreage.

Economy

Umatilla County is one of Oregon's leading agricultural producers. In 2002, Umatilla County ranked seventh in the state for total value of agricultural products sold, at approximately $205 million dollars.[11] The Country ranked first in the state in the

[9] WSTPC, 2005
[10] NRCS, 2005
[11] NASS, 2002

production of wheat and green peas (264,260 acres and 19,439 acres, consecutively) and second in the State in the production of potatoes and vegetables harvested (11,842 acres and 24,768 acres, consecutively).[11] In 2004, the gross farm and ranch sales in Umatilla County were approximately $223 million dollars.[11]

According to the Oregon Employment Division (2004b):

> *Umatilla County has many advantages that make it unique for a rural county located far from Oregon's major population centers. Transportation is a big advantage, with Interstate 84 heading east to west, and Interstate 82 traveling north into the Tri-Cities area of Washington. In addition to major highway transportation systems, the county has significant water transportation facilities along the Columbia River and rail transportation services. Couple these amenities with natural gas transmission lines and an electrical transmission grid, and it becomes apparent that Umatilla County has much to offer.*

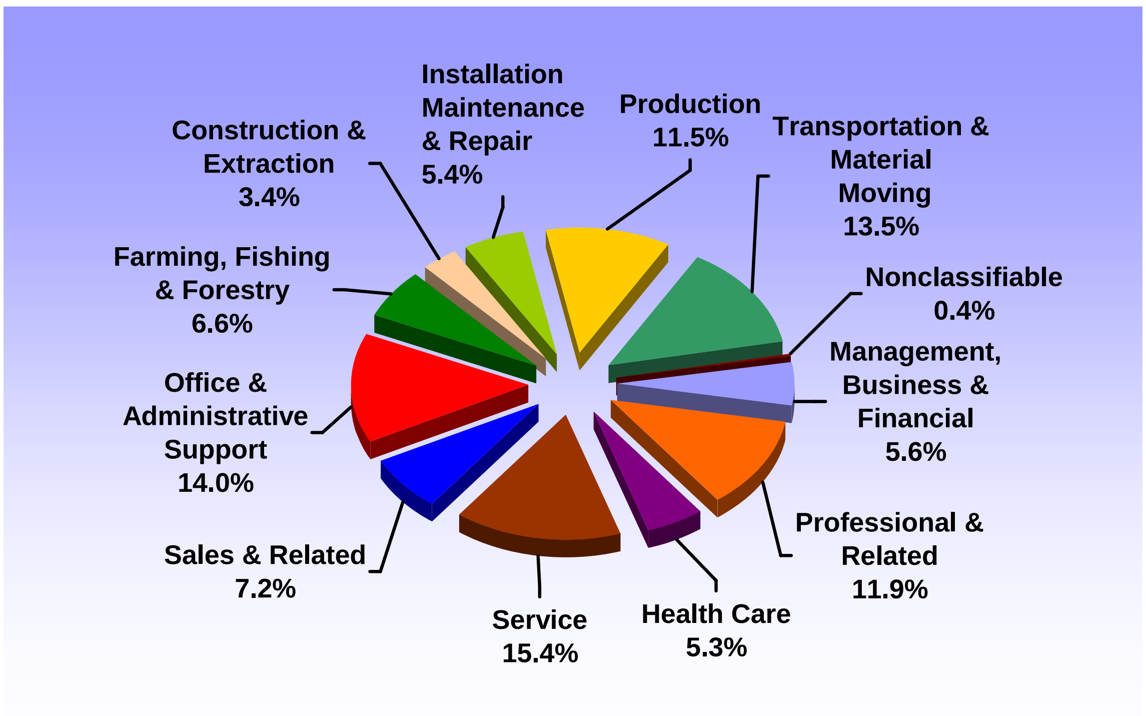

Figure 4: Employment by Occupational Group. The occupational groups that employed the most people in the Morrow & Umatilla Counties (Region 12) were Service (15.4%), Office & Administration Support (14.0%), and Transportation & Material Moving (13.5%).

According to a recent publication by OSU Extension , a comparison of regional economies demonstrated that in relation to the rest of the state, Umatilla County is more specialized in farming, agricultural services, forestry, and other, mining, construction, transportation and public utilities, retail trade, and both the Federal and State/local government sectors. By applying the idea that a region's economy is "based on its exports to markets outside the region (p.12), the researchers used a model (IMPLAN) to estimate exports for each of the different sectors. They determined the following:

Table 2. Umatilla County Sectoral and Export-Base Dependent Employment, 2000.*

Sectoral Employment			Export-Dependent Jobs				
Sector	Jobs	%	Direct	Indirect	Induced	Total	Index (%)
Agriculture	4,630	11.8	3,382	1,195	583	5,159	13.1
Mining	75	0.2	99	15	31	144	0.4
Construction	2,575	6.6	2,273	943	1,089	4,304	11
Manufacturing	4,641	11.8	4,480	2,946	1,852	9,278	23.6
Fabricated Metals	26	0.1	41	10	10	61	0.2
Industrial Machinery	100	0.3	62	24	23	109	0.3
Electrical Equipment	11		7	3	3	13	
TCPU	2,168	5.5	634	357	283	1,273	3.2
Wholesale Trade	1,253	3.2	245	56	80	381	1
Retail Trade	7,015	17.9	1,937	195	382	2,513	6.4
FIRE	1,817	4.6	96	39	31	166	0.4
Misc. Services	7,993	20.4	729	142	167	1,037	2.6
Professional Services	753	1.9	333	43	79	455	1.2
Government	6,186	15.8	5,255	152	1,859	7,266	18.5
Households					7,085	7,085	18.1
Total	39,244	100	19,571	6,118	13,555	39,244	100

*Data source: Edited 2000 IMPLAN Data.

Figure 5: Umatilla County Employment and Export Base

…the most critical sectors in Umatilla County's export base, ranked by index, are: Manufacturing (23.6 percent), Government (18.5 percent), Households (18.1 percent), Agriculture (13.1 percent), Construction (11.0 percent) and Retail Trade (6.4 percent). These six sectors represent over 90 percent of the county's export-based employment. The farms and ranches described at the beginning of this report are an important part of the economy of Umatilla County. However, as the index numbers above and experience on the ground shows, Umatilla County's economy has diversified significantly over the years. (p.14)

According to the Oregon Economic and Community Development Department, the economic status of Umatilla County is considered to be "severely distressed" (along with 15 other counties in the 36-county State of Oregon).[12] This designation is apparently due to the fact that the unemployment rate in Umatilla County is higher (9.4%) than the state average (6.8%).[12]

[12] ECDD, 2006

Water - The Basics

Understanding the components of the hydrologic cycle is valuabe to understanding water resources in the Umatilla Basin.

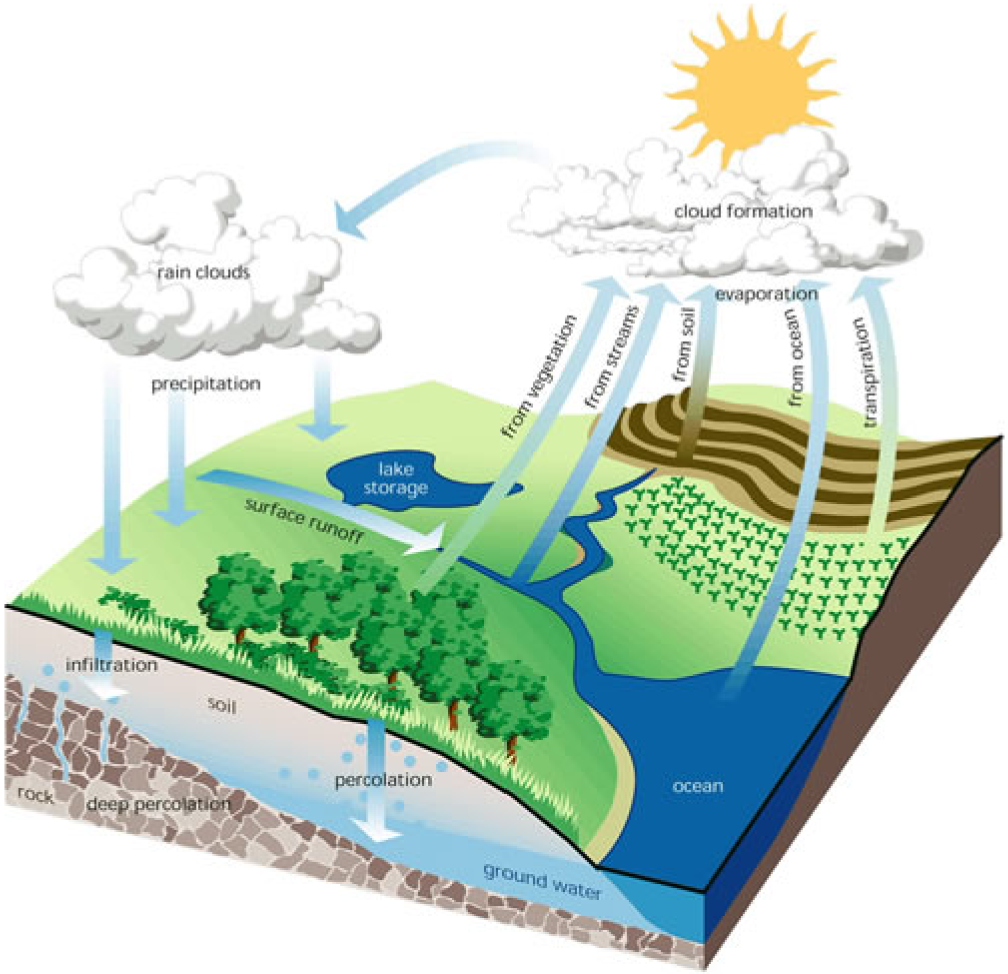

Figure 6: The Hydrologic Cycle (FISRWG,1998)

There is always some water vapor in the air, even when we don't see it. Once that water finds some little nuclei to form a droplet around, clouds begin to form. And once those clouds get heavy enough, they release water as <u>precipitation</u>, which includes rain, sleet, snow, or hail. Precipitation, once it lands on the earth's surface, may either flow over the land (<u>runoff</u>) or soak into the soil surface (<u>infiltration</u>). Water that infiltrates into the soil may evaporate (turn into a gas, vaporize) either through direct contact with the air (<u>evaporation</u>) or by moving through a plant (<u>transpiration</u>). It is common to refer to evaporation as transpiration together as *evapotranspiration*. If water is not lost to the atmosphere, it may percolate. <u>Percolation</u> is the process by which water trickles deeper into the Earth, reaching the water table, or groundwater surface. Groundwater is often challenging because it is not easily observed like surface water.

Hydrogeology

Groundwater is located beneath the ground surface in soil and rock pore spaces and in the fractures of rock formations. An aquifer is a geologic formation (layer of rock or sediment) that can yield a useable quantity of water. There are two main types of aquifers in the Umatilla Basin - alluvial aquifers and basalt aquifers. In order to understand how these formations hold water, it is helpful to understand the processes that formed them.

Geologic Setting

A turbulent past created the land through which the Umatilla River flows today. From about 16-million years ago to about 10-million years ago, massive volcanic eruptions spewed lava from fissures in the Earth's crust. About 300-separate lava flows poured out of the earth and cooled into basaltic rock during this time period. Since each flow can range in thickness from 3 to 300-feet, the total thickness of all the flows can be greater than 10,000-feet.[13] These rocks, the remnants of those enormous eruptions, are collectively referred to as the Columbia River Basalts (CRB).

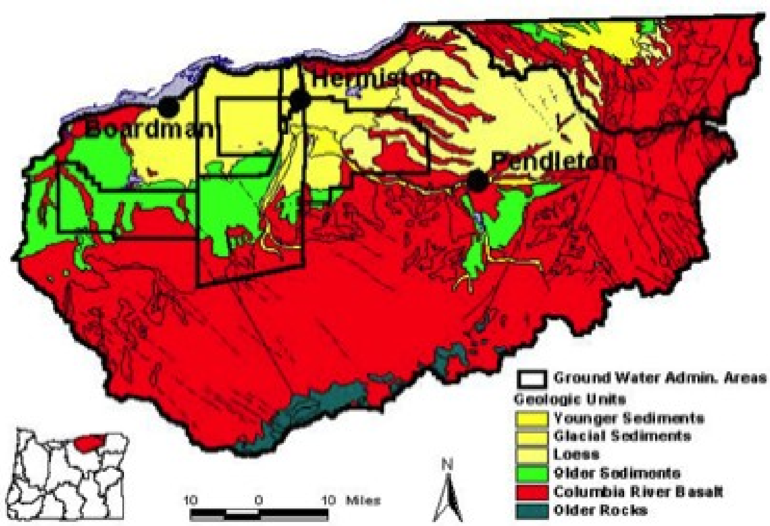

Figure 7: Simplified Geology of the Umatilla Basin (OWRD, 2003)

In the time between CBR flows, weathering and erosion broke up the top layer of the hard, black basalt; as new flows surged over the old, they created layers of breccia, or rubbly, broken-up rock. Sedimentary deposits are present between some basalt flows. These layers were formed during periods of volcanic inactivity, when streams, lakes, and soil horizons formed on the basalt surface.[14] While the middle of each basalt flow is dense and transmits little water, the interflow zones of breccia and sediment form productive aquifers.

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[13] USGS: Davies-Smith et-al, 1988
[14] Oberlander, 1981

Around the same time that the Columbia River Basalts were being formed, regional uplifting began creating the Blue Mountains. Basins and uplands began to form, rivers and streams began to run, and in some places, the running water left sands, gravels, and boulders, materials known as alluvium. These places, past riverbeds and flood deposits, are today's alluvial aquifers.

Overview of Local Groundwater Conditions

Groundwater stored in the basalt aquifers is generally limited to interflow layers (or in rubble zones) between basalt flows. The basalt layers overlying the rubble zones is typically less permeable than the rubble zones, and the water in the aquifer is pressurized. In some cases, the pressure in the aquifer is sufficient that historical drilling into it creates flowing, artesian wells. Recharge to the basalt aquifers occurs primarily in the Blue Mountains, where precipitation is highest, and where permeable interflow zones are exposed at the surface by the tilting of the geologic layers.[14] The water may either flow directly into the interflow zones, or (more likely) down through the faults and into the interflow zones. Areal infiltration of precipitation and snowmelt in the Blue Mountains is probably the most significant source of recharge, vs. selective recharge through permeable zones. Faults are likely to be barriers to recharge and flow.[15]

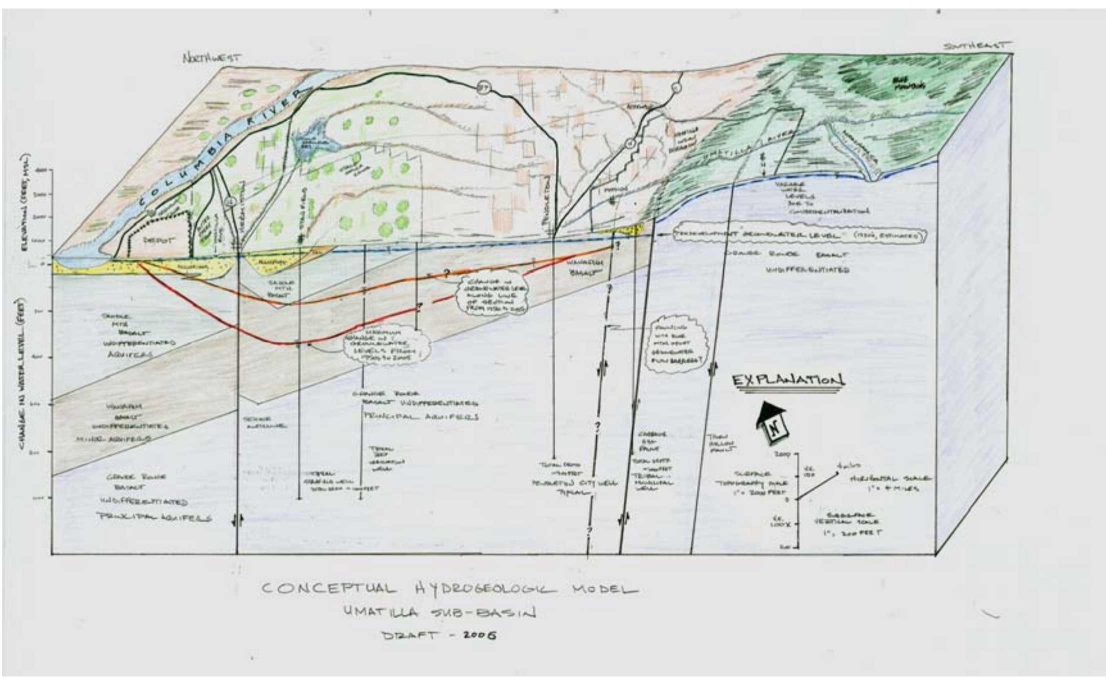

Figure 8: Conceptual Hydrogeologic Model of Umatilla Sub-Basin (See Appendix C for enlarged version)

The water that recharges the aquifers in the Blue Mountains probably takes thousands of years to flow to the lower (northern) part of the basin – one study [13] found that the average age of water taken from several wells throughout the lower basin was 16,500

[15] Hansen et al, 1996

years. This was based on Carbon-14 dating, which indicates the amount of time that has passed since the water was exposed to atmospheric carbon dioxide.[13] In the lower basin, where the interflow zones are parallel to the land surface, a very small percentage of the recharge comes from the land surface (and most of that is through wells) [16] however the extent of recharge through wells is unknown.

However, in contrast, recharge from land surface in the lower part of the basin is low because sources of recharge, especially precipitation, are quite small, not because the interflow zones are parallel to land surface. In fact, because structural dips of the basalt flows are generally only a few degrees in the basin, interflow zones are largely sub-parallel to land surface everywhere.[17] Additionally, according to Wozniak, commingling of the aquifers in the Basin is a problem but the recharge through the wells is in question.

In the Umatilla Basin, the alluvial aquifers are typically shallow. The alluvium (sand, gravel, silt and clay) is on average 50 to 100-feet deep from the land surface; the maximum depth is about 200-feet [18] (see Figure 8). The sediments that form the alluvial aquifer were deposited during the Glacial Lake Missoula floods.

The alluvial aquifer is unconfined, which means that it is recharged directly from the land surface and has a strong connection with surface water bodies. Alluvial aquifers are also characterized by high porosity. Porosity is a measure of the pore space, or the space between gravels or sands that may be filled with water. Typically, alluvial deposits are made up of as much as 30 to 35% pore space. This means that when water is available, they can sustain high pumping rates. Water stored in the alluvial aquifer behaves in a relatively predictable manner to pumping. Whereas the response to pumping the underlying basalt aquifer has a high degree of uncertainty due to the unique storage characteristics in the rubble zones.

Groundwater and Surface Water Connectivity

In some areas of the Basin surface water and groundwater are hydraulically connected, or operate as one resource. They do not operate as two separate resources, as conventional wisdom of water management in the western United States believed for many decades. Elsewhere in the Basin, the surface water and groundwater resources are not in direct hydraulic communication. The intensive use of groundwater is reflected in the decreasing water levels in wells across much of Umatilla County, and as decreased stream flows (baseflow) in some stream reaches.

[16] Ely, 2001
[17] Wozniak, 2006
[18] OWRD, 2003

Overview of Oregon Water Law

Under Oregon law, all water belongs to the public.[19] The Oregon Water Resources Department (OWRD) manages the water resources in Oregon. The mission of the OWRD is "to serve the public by practicing and promoting wise long-term water management". This mission is achieved through two key goals: (1) directly addressing the water supply needs of Oregon, and (2) ensuring the long-term sustainability of Oregon's ecosystems, economy and quality of life by restoration and protection of stream flows and watersheds.[20]

ORWD may issue a permit to use surface water or groundwater, subject to four basic requirements:

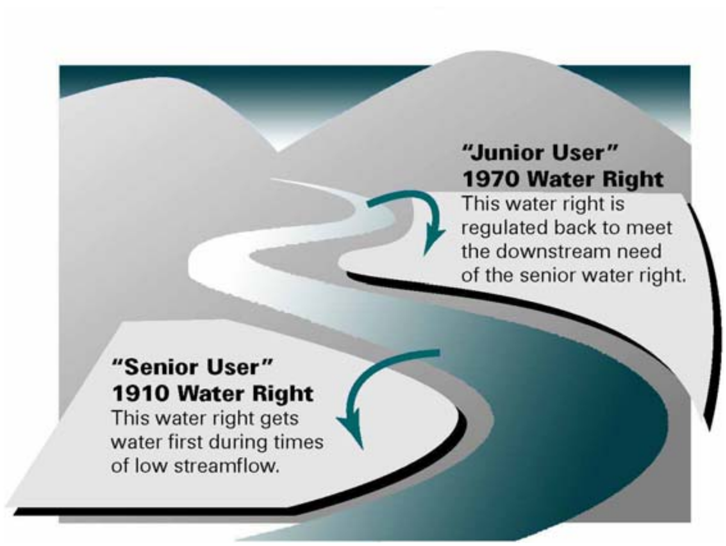

Figure 9: The "Prior Appropriation" Doctrine. The location along a stream (or overtop of an aquifer) is irrelevant. What matters is propriety according to time (diagram courtesy of Robert Rice-OWRD, 2004).

(1) Beneficial use: water must be put to the specific use stated in the water right. The uses include irrigation, industrial, municipal and instream uses

(2) Priority: Oregon water law follows the doctrine of "Prior Appropriation", often summarized as "first in time, first in right." In times of low water availability, water users with the oldest priority date have the right to use the amount specified on their certificate before junior users are entitled to exercise their water rights (see Figure 8).

(3) Appurtenancy: the water right is attached to the land where it is used. If the land is sold, the certificate stays with the land and goes to the new owner.

(4) Must be used: in order to remain valid, a water right must be used as defined on the certificate at least once every five years.

All water rights state a specific rate at which water can be diverted (the "rate") and irrigation and agricultural water rights specify a maximum amount of water that can be applied per acre (the "duty") and a season of use.

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19 Bastasch, 1998
20 OWRD, 2006

Some uses, referred to as exempt uses, do not require a permit from the OWRD. These surface water exempt uses include stock watering and rainwater collection. In the case of groundwater, exempt wells (such as domestic wells that irrigate ½ acre or less and pump less that 15,000 gallons per day) do not require a water right, however the owner is required to submit a well log and the OWRD assigns a priority date when the well is drilled. Even though the exempt wells do not require permits, the OWRD may still regulate them by priority date to protect senior users.

Overview of Water Development in the Umatilla Basin

Examination of the chronology of water development in Appendix B reveals that irrigation began in 1862 in the Umatilla basin. The first well was drilled in the Butter Creek area in 1925, with irrigation use of groundwater starting in the 1950's. Declining water levels have been evident in the Umatilla Basin since about the late 1960's according to the report "Groundwater Supplies in the Umatilla Basin".[18] The OWRD responded by imposing regulatory measures resulting in the designation of the Ordnance, Butter Creek and Stage Gulch Critical Groundwater Areas and the Ella Butte Groundwater classified area.

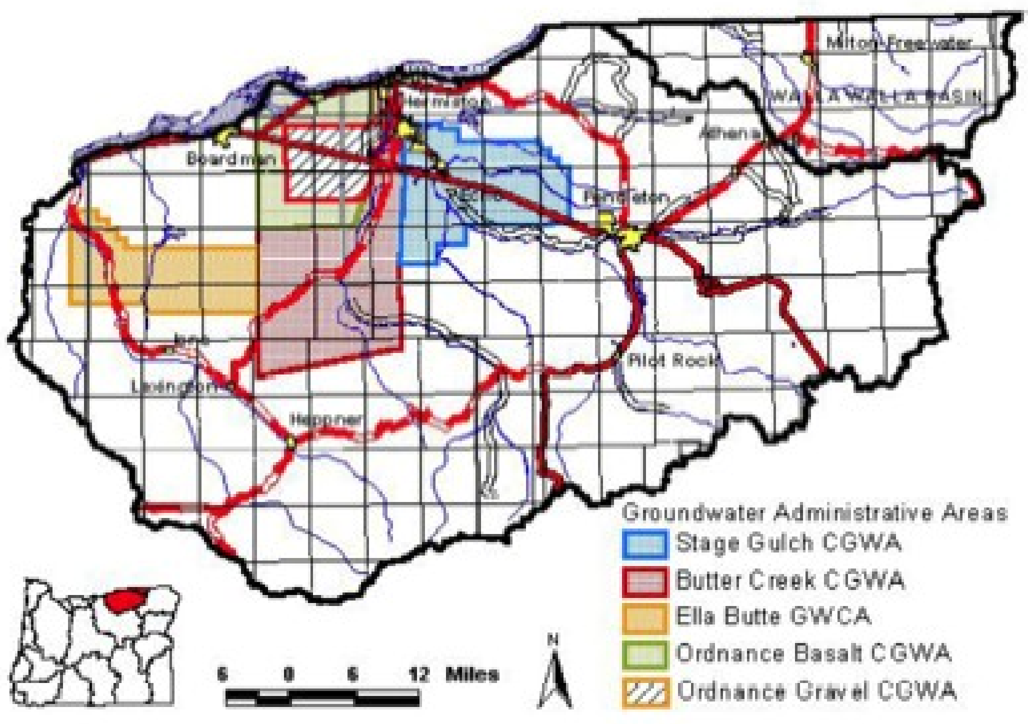

Figure 10: Groundwater Administrative Areas within the Umatilla Basin (OWRD, 2003)

Within these Critical Groundwater Areas, no new permits to appropriate groundwater are issued. The OWRD determines the amount that a water right holder within a designated area can use (known as an allocation), based on the "sustainable annual yield" of the aquifer. For the most part, groundwater level declines have been significantly reduced in most of the controlled area, and declines have arrested in some parts following imposition of these regulations.[18]

The problem today is that groundwater level declines are becoming evident in areas outside of the controlled areas. According to a recent OWRD report ("Groundwater Supplies in the Umatilla Basin", 2003):

> *Groundwater overdraft continues to be a significant issue in the Umatilla Basin. Declines in groundwater levels are evident in areas outside of the controlled areas and, to some extent, within the controlled areas. These declines are focused in and around the cities of Boardman, Adams, Athena, and Pendleton.*

Also, interference between users is becoming a significant issue. Interference is when the pumping of one well creates a cone of depression that impacts another user's well. This can cause the affected water users to pay increased pumping costs, or to not be able to satisfy their water right. Just as the pumping of one well can effect a neighbor, pumping groundwater can, in effect, remove water (know as base flow) from a river or stream and interfere with surface water supplies and rights.[18]

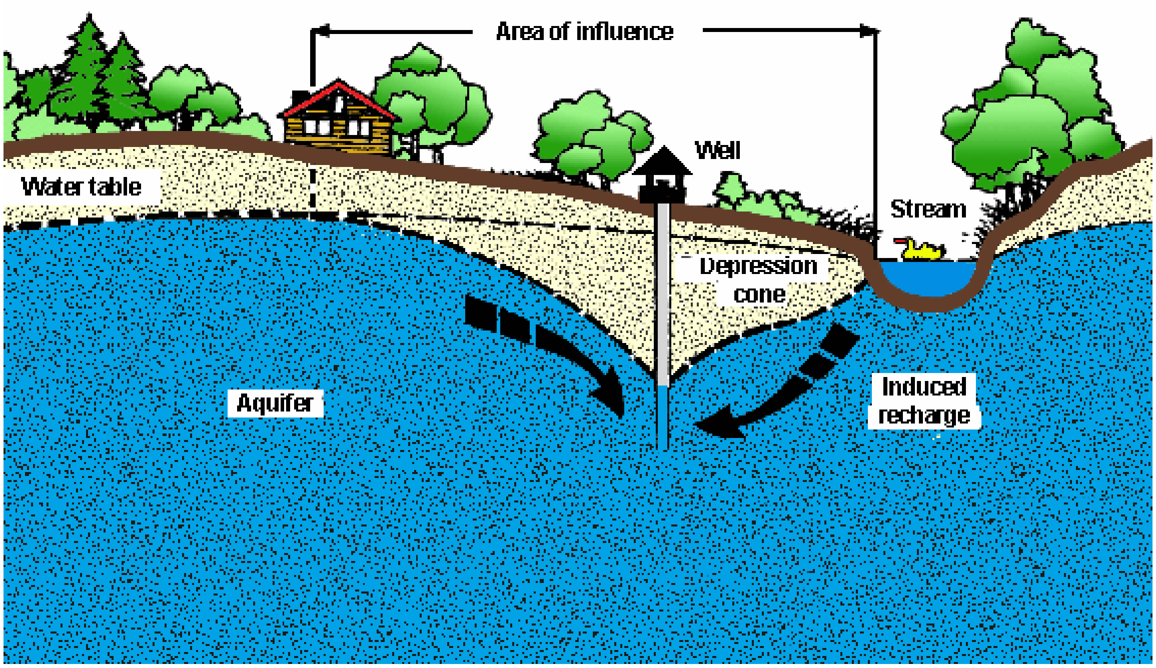

Figure 11: The cone of depression from a pumping well may extend to a nearby stream. Thus well operation may lower the water table below the stream. As a result, the stream loses surface water to the pumping well as a function of the well operation (OSU Well Water Program, 2001).

A Snapshot of the Water Rights in Umatilla County

The following table is a first order approximation of water rights in Umatilla County. However, according to the OWRD these data can be contested because "the table contains many various errors and omissions that are probably due to lack of knowledge of the underlying source data. For example, irrigation rights can be primary or supplemental. A supplemental right must overlie a primary right, must be derived from a different source, and can only be used to make up a deficiency in the primary right. Therefore, since supplemental rights replace primary right, they cannot be added to primary rights to determine the maximum allowable irrigation use.

Also, since the use of a water right can be limited to a specific time of year or can vary throughout the year, each use on a right has a time period associated with it. Therefore, permitted rates in OWRD's water rights database cannot simply be summed up to get a reasonable total (i.e. a rate for January to March and a different rate for April to October do not add up to the total of the two rates for the year).

The two factors listed above lead to some rather large overestimates of permitted irrigation use based on OWRD's water rights database. For example, a quick check of irrigation rights valid for use in July for the basin (excluding the Walla Walla sub-basin) shows 2,167-acres of primary surface water irrigation, 440-acres of supplemental surface water irrigation, 619-acres of primary groundwater irrigation, and 237-acres of supplemental groundwater irrigation. Although this is based on a more recent dataset than the one used for this report, these totals suggest that the report overestimates surface water irrigation by about 860-cfs and ground water irrigation by about 238-cfs."[17]

Umatilla County (Excluding the Walla Walla Sub-Basin Water Rights) in cubic feet per second		
	Surface water	Groundwater
Agriculture	0.02	0.00
Commercial	6.00	35.89
Domestic	14.91	3.82
Fish	73.61	0.41
Instream	0.00	0.00
Irrigation	3026.58	857.34
Livestock	147.15	0.00
Mining	0.00	1.00
Misc.	75.71	6.11
Municipal	188.50	148.95
Power	108.00	0.00
Recreation	2.00	0.44
Wildlife	16.03	0.41
This information is from a spreadsheet distributed by the OWRD entitled Water_Rights_10_18_05_umat_merged.		

Figure 12: First Order of Magnitude of Water Rights

From this example we see that any attempt to quantify water use as a function of water rights is complex. Another consideration is that the water rights data presented on the OWRD is only a snapshot in time and can not be relyed on over the longterm. This seems to be an unresolved issue that will require counsel from OWRD if it is to have merit as a tool for analysing water useage in the Basin. A better understanding of the underlying source data may be developed through additional guidance from OWRD and experienced water rights attorneys.

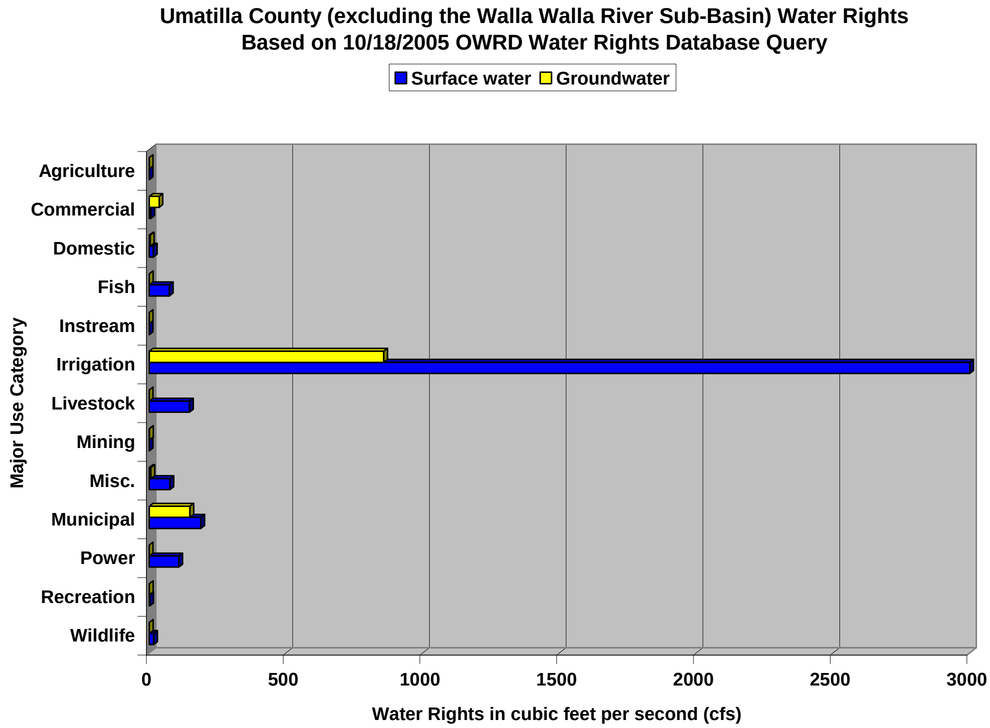

Figure 13: Graphic Presentation of First Order Estimate of Water Rights

What Has Been Studied?

The Umatilla Basin is one of the most studied basins in Oregon. As water development evolved with changing water needs, new technology, and changing values as outlined in the Water Chronology (summarized in Appendix B) so too did the breadth of scientific and economic studies. Many of the published and unpublished reports were prepared to address site-specific problems. For example, irrigation shortage studies were typically completed for only western Umatilla County areas. Elsewhere in the Umatilla Basin, the studies on groundwater resources were more regional in extent. Studies also focused on water quality issues; some focused strictly on the lower Umatilla Basin to support the depletion of a Groundwater Management Area [21] due to nitrates in the shallow, alluvial groundwater or were completed in response to the "Superfund" law investigating the legacy of World War II and the Cold War at the Umatilla Army Depot.

Water planning studies are limited in breadth, partly due to the fragmented nature of Oregon's land use laws and water laws; also in part to due to budget cuts to the Oregon Water Resources Department (OWRD). The last comprehensive look at water resources in the Umatilla Basin by OWRD was in 1988 following the adoption of the Critical Groundwater Areas in the Ordnance Basalts, the Ordnance Gravels, and the Butter Creek

[21] Grondin, Wozniak et al, 1995

Area in 1976. Shortly thereafter additional areas were designated as Critical Groundwater Areas – Stage Gulch was designated as a Critical Groundwater Area for the deep basalt in 1991.

More recently, water studies have focused on restoration of fisheries, such as the Columbia River Intertribal Fish Commission Plan to restore anadromous fish in the Columbia Basin in 1995, followed by the Oregon Plan for Salmon and Watersheds in 1997. In related studies, the Oregon Department of Environmental Quality identified reaches of the streams and rivers that violated Total Maximum Daily Load (TMDL) standards of the Federal Clean Water Act.

But the continued decline of the groundwater levels in the deep basalt aquifers underlying the Umatilla Basin has spurred efforts to slow the measured decline in storage of groundwater. The City of Pendleton is experimenting with injecting water underground in what has been referred to as Aquifer Storage and Recovery (ASR). Studies by groundwater scientists have suggested the deep groundwater stored in the basalt aquifers is nearly 20,000 years old.[22]

Many, but not all, of the Municipalities within the Basin have Water Conservation Plans, which provide information relating to the water system, water sources, and the plans to manage and conserve water supplies to meet future needs. The cities that do have plans are:[23] Adams, Athena, Helix, Hermiston and Pendleton. Water usage reports (quantifying total water usage by month and year) as well as pertinent water rights information for all municipalities were located on the OWRD website.

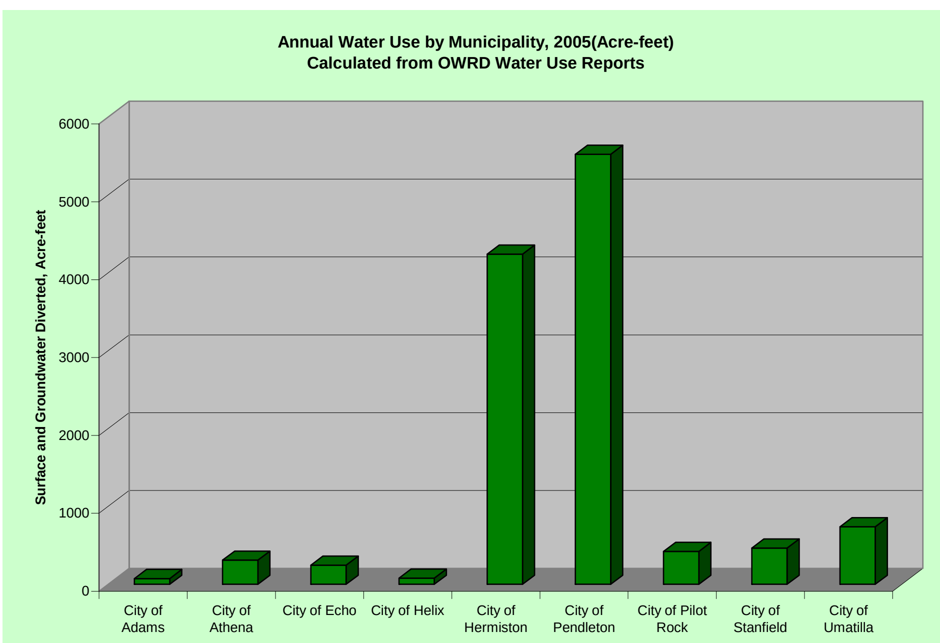

Figure 14: Annual Water Use by Municipality, OWRD

[22] Larson et al., 2000
[23] OWRD Pendleton, March 2006

Municipality	Total Consumed, 2005(AF)	*Total Permitted (AF) (estimated)*
City of Adams	74	*724*
City of Athena	310	*3140*
City of Echo	245	*6429*
City of Helix	78	*977*
City of Hermiston	4242	*23075*
City of Pendleton	5523	*53847*
City of Pilot Rock	421	*3388*
City of Stanfield	465	*21322*
City of Umatilla	737	*13792*
This information is based on the "water use reports" that are available on the OWRD website. http://www.wrd.state.or.us/OWRD/WR/water_use_report.shtml		

Figure 15: Municipal Water Usage and Totals Permitted, OWRD. Note the municipal water usage of the Confederated Tribes of the Umatilla Indian Reservation is not tabulated.

Reviews of the reported information by OWRD staff suggest that some errors and omissions, along with limited "double counting" of the reported data may be listed in these charts and tables underscoring the complicated nature of reporting water consumption and water rights data retained by OWRD. Likewise, these compilations or water rights data retained by the Confederated Tribes of the Umatilla Indian Reservation.

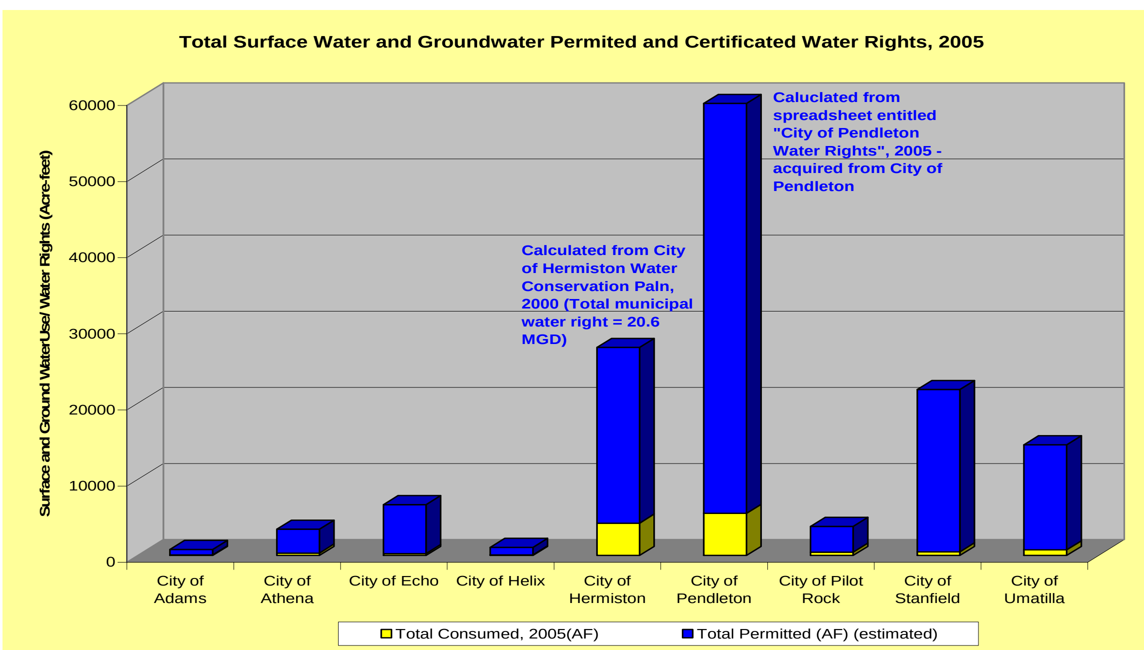

Figure 16: Total Surface and Groundwater Permitted

<u>Generalized Observations and Conclusions on Groundwater Usage</u>

A recent publication discusses how the government encouraged agriculture and industrial production in the Boardman-Ordnance-Hermiston area of Morrow and Umatilla Counties in 1963, when Governor Mark Hatfield brokered an option with

Boeing Co. on nearly 100,000-acres near the Boardman bombing range. This included nine water rights for irrigation of more than 63,000-acres.[24] Severe declines in groundwater were observed in the late 1960's and within twenty years the water levels had dropped over than 300-feet in some wells. This is an important topic because in the years that followed significant groundwater depletion in the region occurred, and conflicts over water permits and extensions were highly contentious and debated through the late 1980's. It is important that this history is re-evaluated because relics of this type of water policy are relevant as new water policy decisions are developed. The diversity of the community would ultimately have greater representation in future water policy.

The natural hydraulic system compared to the modified hydraulic system that was addressed by a 1988 USGS report entitled "Geohydrology and Digital Simulation of the Ground-water Flow System in the Umatilla Plateau and Horse Heaven Hills Area, Oregon and Washington".[13] A "three-dimensional finite-difference model" was used to simulate groundwater conditions in a 5,800-square mile area that emphasized the 3,800-square mile area in Oregon designated as the Umatilla Plateau. This area includes parts of Umatilla, Morrow, and Gilliam Counties, so the results of the model do not apply only to the Umatilla Sub-basin. However, the areas of the most intensive development have been in Umatilla County or near the Umatilla County line.

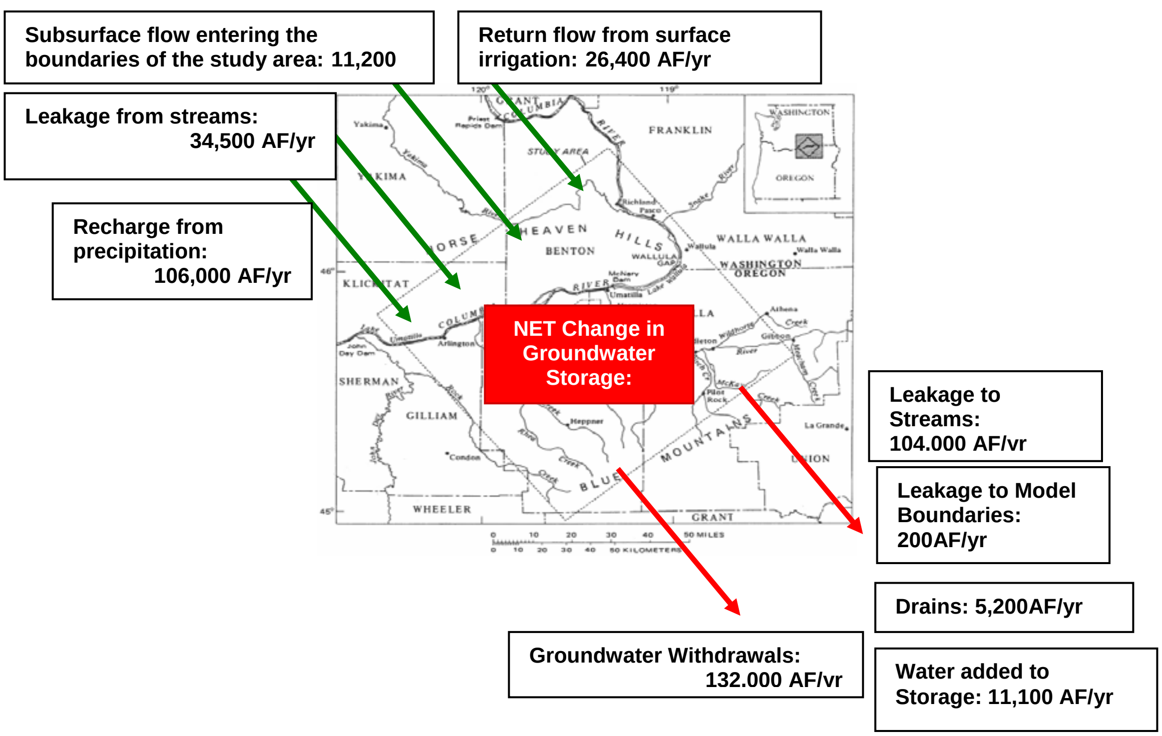

Figure 17: Post-development (1982-1985) Groundwater Budget, with emphasis on the Umatilla Basin. Adapted from Davies-Smith, Bloke & Collins, 1988

[24] Orr & Orr, 2005

After Davies-Smith and others (1988). Ground water model budgets in acre-feet/year.		**Pre-development (Pre-1950)**	**Post-development (1982)**	**Difference (Post – Pre)**
Inflow to ground water system	Recharge from precipitation	106,000	106,000	0
	Leakage from Streams	22,700	34,500	**11,800**
	Subsurface inflow from model boundaries	10,800	11,200	400
	Infiltration from Surface water irrigation	0	26,400	26,400
	Total inflow	**139,500**	**178,100**	38,600
Outflow from ground water system	Drains	5,200	5,200	0
	Leakage to streams	134,000	104,000	**-30,000**
	Leakage to model boundaries	200	200	
	Ground water pumpage	0	132,000	132,000
	Water added to storage	0	11,100	11,100
	Total outflow	**139,400**	**252,500**	113,100
Net Change in Storage AF/yr (In-Out)		**100**	**-74,400**	

Figure 18: This table shows the results of a simulated groundwater flow study completed by USGS. Results are representative of an area much greater than the Umatilla Basin. From Davies-Smith, Bolke, and Collins, 1988.

One of the most useful purposes of this kind of modeling is to determine the impacts of ground water pumping. A comparison of the post-development model to the pre-development model indicates that of the 132,000 acre-ft (AF) of ground water pumped in 1982: 74,400 AF came from storage; 11,800 AF came from increased leakage from streams; 30,000 AF came from decreased leakage to streams; and 15,300 AF came from the withdrawal of infiltrated water from surface water irrigation. The two biggest components of this change are groundwater storage losses (74,000 AF) and decreases in stream flow (41,800 AF).

Who is Using the Water Resources in the Basin?

The USGS published a report in 1996 entitled “Estimated Water Use and General Hydrologic Conditions for Oregon, 1985 and 1990”. These two pie charts represent a condensed version of what was presented in the report. The values represented below were reported in million gallons per day, and were converted to acre-feet per year. The values represent total withdrawals from surface water and groundwater. According to Broad and Collins (1996), 270-million gallons per day (MGD) were estimated to be withdrawn for irrigated agriculture in 1990. This converts to about 830-AF/day or 174,000-AF/yr based on a 210-day irrigation season.

Water Resources Usage in Umatilla Basin, 1999 (MGD)[1]						
Usage Category	Self-Supplied		Public Supplied	Reclaimed Water	Conveyance Losses	Consumptive Usage
	Ground	Surface				
Domestic	1.6	0.1	5.8	0.0	1.2	2.0
Commercial	0.1	0.1	1.9	0.0		0.4
Industrial	5.3	0.0	0.1	0.0		3.3
Livestock	0.4	0.5	0.0	0.0		1.0
Irrigation[2]	59.0	210.0	0.0	3.0	80.0	180.0

1 MGD = Million gallons per day

2 Irrigation season is approximately 210-days per year

Figure 19: Withdrawals and Uses

From the 1999 report entitled "Hydrologic Model Development Lower Umatilla Basin" [25] which primarily addresses surface water use; there are five major trends in irrigated agriculture that have occurred in the basin:

(1) Conversion from flood irrigation to center pivot or drip systems

(2) Conservation from irrigation efficiency improvements driven by increases in irrigation power bills

(3) Agreements with the U.S. Bureau of Reclamation (USBR) to reduce irrigation water diversions to restore fish flows downstream from McKay Reservoir

(4) Agreements with the USBR for the exchange of water from the Columbia River for water left in stream in the Umatilla River, and

(5) Increases in irrigation district service areas resulting from increased conservation.

All values are based on the report "Hydrologic Model Development Lower Umatilla Basin", prepared for the United States Bureau of Reclamation by CH2MHILL, May 1999.						
Irrigation District	**Total surface water usage**	**Time period of record**	**Columbia River average annual pumpage**	**Time period of record**	**Umatilla River Diversions** (* denotes values estimated by subtraction)	**Time period of record**
West Extension (WEID)	30,580 acre-feet (estimated)	1993 - 1997	15,350 acre-feet (Phase I)	1993 – 1997	15,233 (HMD, p.A-2)	1993-1997
Hermiston (HID)	51,973 acre-feet (Feed Canal) and 6,767 acre-feet (Maxwell) minus exchange water (HMD, p.A-2)	1995-1997	1,662 acre-feet (Phase II)	1995-1997	57,078 acre-feet *	
Stanfield (SID)	31,400 acre-feet (HMD, p.A-3)	1991-1997	8,550 acre-feet (Phase II)	1996-1997	22,850 acre-feet*	
Westland (WID)	65,740 acre-feet (excluding Allen Ditch but inclusive of County Line Water Improvement District) (HMD, p. A-4)	1991-1997	Phase III?		26,570 acre-feet (HMD, p.A-3)	1992
Teel (TID)	4,500 acre-feet storage from McKay, plus 1,000 to 7,000 acre-feet flood water diversions	1992				

Figure 20: Hydrologic Model Development of Lower Umatilla Basin

[25] CH$_2$MHill, 1999

Other Water Resources Issues

Fish and Wildlife

From the "Umatilla River Sub-basin Agricultural Water Quality Management Plan" (URSLAC, 2003):

> The Umatilla River sub-basin supports a variety of anadromous and resident fish; both cold and warm water species. The historical abundance of the basin's anadromous fish resources, including fall and spring Chinook, Coho and steelhead, has been greatly diminished. The bull trout and summer steelhead are listed as a threatened species under the federal Endangered Species Act (ESA). Recovery efforts have resulted in the restoration of Chinook and Coho salmon runs in the basin. The Umatilla River sub-basin is home to four indigenous species of fish that qualify as Sensitive, Threatened or Endangered under either the federal ESA or Oregon's Sensitive Species Rule (OAR 635, Division 100) as identified in Figure 21 below.

SPECIES	ESA STATUS	SENSITIVE SPECIES STATUS
Bull Trout	Threatened	Critical
Summer Steelhead	Threatened	Vulnerable
Redband Trout		Vulnerable
Margined Sculpin		Vulnerable

Figure 21: Indigenous Fish Species in the Umatilla Sub-basin

Water Quality

The "Umatilla River Sub-basin Agricultural Water Quality Management Plan" [26] (provides a complete overview of water quality in the area. Below are excerpts from that report.

303(d)-Listed Streams

Approximately 40-river/stream segments in the Umatilla Basin have been declared "water quality limited" by the DEQ under Section 303(d) of the Clean Water Act (CWA). Water quality standards violations occur for temperature, pH, bacteria, nutrients (ammonia and nitrate), turbidity, aquatic weeds/algae, sedimentation, dissolved oxygen, iron, and manganese. Of these, temperature, flow, ammonia, algae, and bacteria are primarily summer concerns. Data collected over the past few years indicates that temperature, sediment, pH and nutrients are interrelated and together lead to conditions that impair beneficial use of the water. Temperature is the most common listing and one of the easiest to quantify as well as the most difficult to affect. Further monitoring and data evaluation will be done to support effective solutions and track progress, and will be the basis for future refinement of this plan.

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[26] URSLAC, 2003

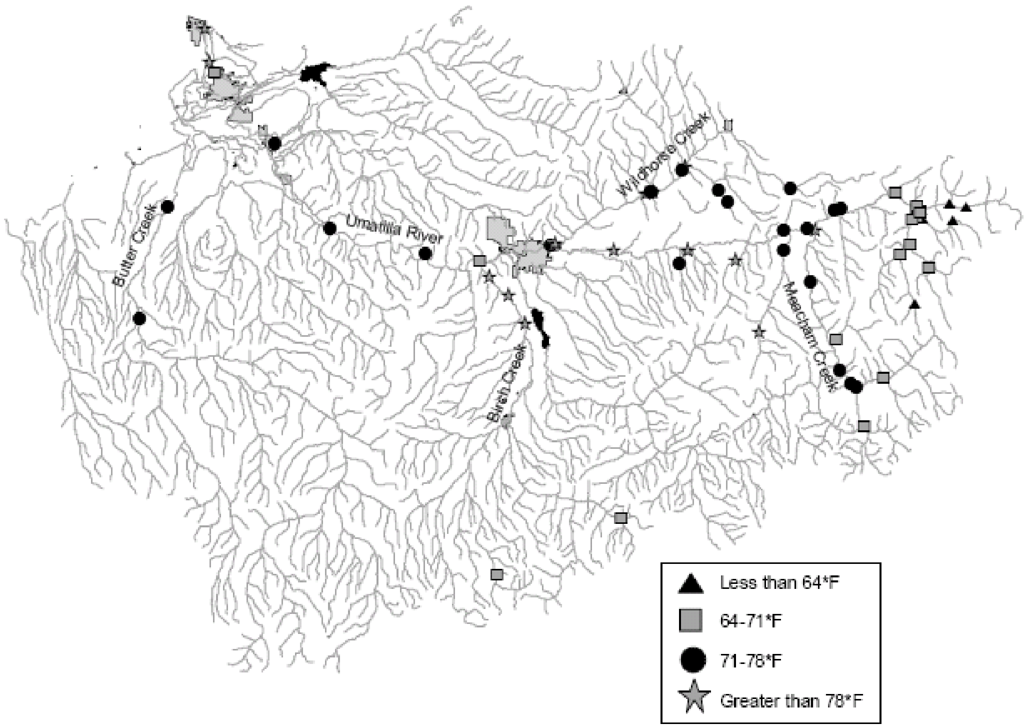

Figure 22: Section 303(d) Temperature Listed Streams, DEQ-TMDL, 2001

Sources of Water Quality Impairment

Sources of water pollution can be generalized into two types: point source pollution and nonpoint source pollution. Point source pollution emanates from clearly identifiable discharge points such as wastewater treatment plants and piped effluent from industrial operations. Permits are required for point source discharges. These permits, administered by the Oregon Department of Environmental Quality (DEQ), require that certain effluent standards be met. Nonpoint source pollution is pollution emanating from landscape scale sources and cannot be traced to a single point.

Nonpoint sources of pollution in the Umatilla River watershed include: eroding agricultural, range and forest lands, eroding stream banks, runoff and erosion from roads and urban areas, runoff from livestock and other agricultural operations, and septic systems. Re-routing of runoff via road building, construction, and land surfacing such as parking areas can lead to excessive erosion or pollutant transport. Pollutants from nonpoint sources are carried to the surface water or groundwater through the action of rainfall, snowmelt, irrigation and urban runoff, and seepage. A major nonpoint source of water quality impairment is heat input, which has increased due to vegetation removal, seasonal flow reduction, changes in channel shape and alteration to the floodplain. Channelization alters gradient, width/depth ratio, and sinuosity, causing sediment and temperature increases.

Within the past 200-years many human activities and natural events have contributed to the watershed conditions that still may affect water quality. Historically, the first Europeans to come to this area were trappers in search of beaver pelts. Nearly complete elimination of beaver began a series of events that changed the natural hydrology of area watersheds. Following further settlement into the area, livestock numbers and grazing practices negatively impacted natural vegetation. Over a quarter million domestic animals grazed this area in the late 1800's. Extensive logging and road building has changed the natural water holding capacity of upper watersheds while extensive cultivation has impacted the lower areas. With development of cropland came diversion of water for irrigation. Federal and state agencies, while implementing what was then "best agricultural or watershed health science", encouraged fire suppression, stream channel straightening, wetland drainage, and other practices that have impacted watershed health and water quality. In addition to the human contributions, the cyclical nature of the climate has produced watershed altering droughts and floods. There exists within the basin an extensive network of public roads. Outside of urban areas, there are approximately 1900-miles of county and state managed roadways that equates to nearly 10,000-acres of impermeable surfaces. These roadways also may form blockages or constrictions to streams and waterways that influence erosion and/or sediment delivery and influence functionality of streams.

Lower Umatilla Basin Groundwater Management Area

In 1990, the Oregon Department of Environmental Quality (DEQ) declared the Lower Umatilla Basin (LUB) a Groundwater Management Area (GWMA) because nitrate-nitrogen concentrations exceeded 7-mg/l in many area groundwater samples. This level is 70% of the Oregon maximum measurable level of 10-mg/l (Federal Safe Drinking Water Standard) and is the trigger level for declaring a GWMA. Under the Oregon Groundwater Protection laws (*ORS 468B.180*), DEQ is required to declare a GWMA if area-wide groundwater contamination is present as a result of suspected non-point source activities.

DEQ and other state agencies conducted a 4-year hydrogeologic investigation to determine the extent of the contamination and to identify the potential sources of that contamination. The technical investigation identified five area activities contributing to nitrate contamination of the groundwater:

- Irrigated agriculture
- Land application of food processing water
- Confined animal feeding operations (feedlots and dairies)
- Domestic sewage where septic systems occur in high densities
- The U.S. Army Umatilla Chemical Depot's washout lagoons

<u>What is Unknown?</u>

Other basins in Oregon are undergoing intensive exploitation of groundwater such as the Deschutes River Basin and the Willamette River Basin have detailed conceptual hydrologic models. Perhaps one of the most important attributes of the basin studies is a detailed hydrologic budget, along with a detailed analysis of the Hydrogeologic controls on groundwater flow. On the basis of this limited summary of the existing information, suggestions for additional Hydrogeologic studies and water planning include the following:

- Maps showing recharge
- Maps showing consumptive use
- Evapotranspiration across the basin is poorly defined
- Deficiency in change in storage, but companion study is addressing
- Change in storage due to change in aquifer permeability
- Actual GW withdrawals and water levels in municipal wells
- GW/SW interaction is known at a limited geographic scale
- Spring impact – rejected recharge
- An analysis of wet water vs. paper water
- Water quality changes associated with intensive pumping are known at a reconnaissance level
- Impact of geologic structures on GW flow
- Conceptual model & boundary conditions for computer analysis are poorly understood

What Are Others Doing?

Groundwater is the world's most extracted raw material. Pumping of groundwater is among the most intensive human-induced changes in the hydrologic cycle. With dramatic changes in drilling technology, pumping technology and the availability of electrical power over the past 60-years, the number of wells has increased exponentially in many parts of the world. A common misunderstanding regarding groundwater resources is that aquifers are constantly being replenished and therefore water is always available. But in certain cases the time period required for replenishment is very long in relation to the normal time-frame of human activity, taking 100's to 1000's of years. When viewed in this context, it is valid to talk of the utilization of non-renewable groundwater or the "mining of aquifer reserves", particularly for purposes of water resources planning.

The focus in Umatilla County, elsewhere in the United States and the world is on management of aquifers with non-renewable groundwater where the "confined sections" of very large aquifer systems, such as the Columbia River Basalt, where groundwater development intercepts or induces little active recharge, and the depth to water falls continuously with abstraction. The increased depth to groundwater with pumping over the past 50-years that is observed in Umatilla County is not unique. Declining water tables are reported for the Ogallala Aquifer or High Plains Aquifer Systems within Midwestern United States - the largest aquifer in North America. Elsewhere in the world, pumping water levels are reported to be declining in China, India, Spain, and the Middle East. Regardless of the location, the social and economic impacts of declining groundwater levels are the same: significant increases in energy costs owing to progressive drawdown; increased costs for operation and maintenance of wells, especially well deepening and deeper setting of pumps; loss of investments due to abandonment of farms; and crop yield losses owing to the increase in water salinity and decreases in basin stream flow.

Management and governance of groundwater are terms that are often used interchangeably in the literature focusing on the institutional aspects of groundwater resources. Groundwater management has traditionally focused on modeling exercises by hydrologists and water managers who formulate and implement groundwater laws, whereas groundwater governance is a holistic approach of inclusion, taking into account the concerns of water scientists & engineers, policy makers, and groundwater users. Few practitioners have suggested a coordinated plan of attack to address these management and governance issues for groundwater, due to the lack of knowledge regarding the spatial and temporal response of groundwater systems to intensive use even in the most studied groundwater systems in the world such as the Ogallala or High Plains Aquifer System in the United States.

Resource economists and geographers suggest that better groundwater governance of the groundwater resources undergoing intensive exploitation means acknowledging a greater role for markets, civil society, local governments, and a much diminished role for the central & state governments. One approach focuses on learning what the groundwater users think should be done for groundwater management – such an approach defines a public participatory approach to resource management. In a unique case study completed in the county of Jordan where water levels in the major aquifers have declined 60 to 100-feet, as compared to the nearly 500-feet in water level decline observed in some areas of the Umatilla Basin, the agricultural community was surveyed as to what they thought needed to be done to curb the water level declines. The farmers ideas for management options included an Irrigation Advisory Service which helped farmers become better informed on water conservation methods; a "buy-out" of wells; a reduction of groundwater pumping by all entities, particularly municipal and industrial use; the metering and water use charges where annual abstraction limits and cropped area limits would be enforced; and exchange groundwater use with treated wastewater. When looking at the bigger picture, the World Bank [27] identified two approaches:

1. In the "planned depletion scenario" for a groundwater system that has not been intensively developed, the management goal is the orderly utilization of aquifer reserves with expected benefits and predicted impacts over a specified time-frame. "Exit strategies" need to be identified, developed and implemented by the time that the aquifer is seriously depleted. This scenario must include balanced socioeconomic choices on the use of aquifer storage reserves and on the transition to a subsequent less water-dependent economy. A key consideration in defining the "exit strategy" will be identification of the replacement water resource, such as desalination of brackish groundwater, increased use of treated wastewater, or importation of surface water.

2. In the unplanned situation such as that underway in Umatilla County, a "rationalization scenario" is needed in which the management goal is to (1)

[27] World Bank.org

> hydraulically stabilize the aquifer, or (2) more orderly utilization of aquifer reserves, minimizing water quality deterioration, maximizing groundwater productivity, and promoting social transition to a less water-dependent economy.

In regards to the concept of using wastewater as a groundwater recharge, public perception is a very important consideration that requires significant preparation. Students from OSU have synthesized social and technical aspects of this topic and prepared the technical briefing in Appendix D. This topic is evaluated on a global perspective for communities experiencing similar problems to those occurring in Umatilla County.

In both cases the groundwater pumping rates will have to be reduced. The “million dollar” question is - What should be done in Umatilla County? This is part of the challenge the Critical Groundwater Taskforce is facing and where the groundwater users may need to help out with some creative ideas.

Most of the published documents are focused on the water issues in the lower basin/western part of the county. We were able to find only two documents that referred to water level declines in portions of the county that were not in West County (executive summary and water resources in the Umatilla Basin).

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GLOSSARY

Adapted from *Estimated Water Use and General Hydrologic Conditions for Oregon, 1985 and 1990* [28]

acre-foot (acre-feet)- the volume of water required to cover 1-acre of land (43,560-square feet) to a depth of 1-foot, equivalent to 325,851-gallons.

alluvium - general term for deposits of clay, silt, sand, gravel, or other particulate material deposited by a stream or other body of running water in a streambed, on a flood plain, in a delta, or at the base of a mountain.

anadromous fish - migratory fish, such as salmon, that are born in freshwater, spend most of their lives in estuary and ocean waters, and return to freshwater to spawn.

application rate - rate at which irrigation water is applied per unit area. (e.g. $1/80^{th}$ of a cubic foot per second per acre is 1/80-cfs/ac)

aquifer - a geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

base flow - sustained low flow of a stream. In most places, base flow is ground-water inflow to the stream channel.

commercial water use - water for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions (both civilian and military). The water may be obtained from public supply or may be self-supplied.

consumptive use - that part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Referred to also as "water consumed" or "water depletion."

conveyance loss - water that is lost in transit from a pipe, canal, conduit, or ditch by leakage or evaporation. Typically, the water is not available for further use; however, leakage from an irrigation ditch, for example, may percolate to a ground-water source and be available for further use.

crop-water need - the amount of water that must be applied by irrigation to a crop to account for evapotranspiration is equivalent to consumptive use.

diversion - a turning aside or alteration of the natural course of a flow of water; the diverted water is normally considered to physically leave the natural channel.

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[28] Broad and Collins, 1996

domestic water use - water used for household purposes, such as drinking, preparing food, bathing, washing clothes and dishes, flushing toilets, and irrigating lawns and gardens. Referred to also as "residential water use." The water may be obtained from a public supply or may be self-supplied.

drainage basin - land area drained by a river.

evaporation - process by which water is changed from the liquid to the vapor state. Also see "evapotranspiration" and "transpiration."

evapotranspiration - a collective term that includes water discharged to the atmosphere as a result of evaporation from the soil and surface water bodies, and by plant transpiration. Also see "evaporation" and "transpiration."

groundwater - generally, all subsurface water as distinct from surface water; specifically, that part of the subsurface water in the saturated zone (a zone in which all voids are filled with water).

head - the difference in elevation in feet between the water surface in the reservoir and the plant tailrace (surface water).

hydroelectric-power water use - the use of water in the generation of electricity at plants where the turbine generators are driven by falling water; an instream use.

hydrologic unit -a region that includes an area drained by a river system, the reach of a river and the tributaries in that reach, a closed basin(s), or a group of streams that form a coastal drainage system.

industrial water use - water used for industrial purposes such as fabrication, processing, washing, and cooling in such industries as steel, chemical and allied products, paper and allied products, mining, and petroleum refining. The water may be obtained from a public supply or may be self-supplied.

instream use - water use within the stream channel for such purposes as hydroelectric-power generation, navigation, water-quality improvement, fish propagation, and recreation.

interbasin transfer - artificial transfer (pipes or canals) of freshwater from one hydrologic unit to another hydrologic unit.

irrigation - generally, the controlled application of water to arable lands in order to supply the water requirements of crops that are not satisfied by rainfall. Irrigation systems used include the following:

> **center pivot** - automated sprinkler irrigation achieved by rotating a sprinkler pipe or boom while supplying water to sprinkler heads or nozzles. The pipe is supported above the crop by towers at fixed spacings and propelled by pneumatic, mechanical,

hydraulic, or electric power on wheels or skids in fixed circular paths at uniform angular speeds. Water, which is delivered to the center pivot point of the system, is applied at a uniform rate by progressive increase of nozzle size from the pivot to the end of the line. The depth of water applied is determined by the rate of travel of the system. Single units are ordinarily about 1,250 to 1,300-feet long and irrigate about a 130-acre circular area.

drip - an irrigation system in which water is applied directly to the root zone of plants by means of applicators (orifices, emitters, porous tubing, perforated pipe) operated under low pressure. The applicators can be placed on or below the surface of the ground, or can be suspended from supports.

flood - the application of irrigation water, whereby the entire surface of the soil is covered by ponded water.

gravity - irrigation in which the water is not pumped, but flows in ditches or pipes and is distributed by gravity.

sprinkler - an irrigation system in which water is applied by means of perforated pipes or nozzles, operated under pressure, to form a spray pattern.

sub-irrigation - a system in which water is applied below the ground surface either by raising the water table within or near the root zone, or by using a buried perforated or porous pipe system that discharges directly into the root zone.

traveling gun - sprinkler-irrigation system consisting of a single large nozzle that rotates and is self-propelled. The name also refers to the fact that the base is on wheels and can be moved by the irrigator or affixed to a guide wire. Also referred to as "big gun."

wild flooding - flood irrigation resulting from a temporary dam (usually rocks and gravel) being placed in a stream that carries snowmelt runoff. The stream overflows, and the resulting flood irrigates surrounding lands.

irrigation district - in the United States, a cooperative, self-governing, public corporation set up as a subdivision of the State government, with definite geographic boundaries, organized and having taxing power to obtain and distribute water for irrigation of lands within the district that has been created under the authority of a State legislature with the consent of a designated fraction of the landowners or citizens.

irrigation return flow - part of irrigation water that is not consumed by evapotranspiration and that migrates to an aquifer or surface water body.

irrigation water use - artificial application of water on lands to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands, such as parks and golf courses.

livestock water use - water used for stock watering, feed lots, dairy operations, fish farming, and other on-farm needs. Livestock, as used here, includes cattle, sheep, goats, hogs, and poultry.

million gallons per day (MGD) - a rate of flow of water.

mining water use--water use for the extraction of naturally occurring minerals, including solids such as coal and ores; liquids, such as crude petroleum; gases, such as natural gas. Also, uses associated with quarrying, well operations (dewatering), milling (crushing, screening, washing, flotation), and other preparations customarily done at a mine site or as part of a mining activity.

normal storage - the total storage space in a reservoir below the normal retention level, including dead and inactive storage but excluding any flood-control or surcharge storage.

offstream use - water withdrawn or diverted from a ground or surface-water source for public-water supply, industry, irrigation, livestock, thermoelectric-power generation, and other uses.

per-capita use - the average amount of water used per person during a standard time period (generally a day).

placer mining - extraction of heavy metals or minerals from surface gravel or other similar deposit by washing the deposits with water.

public supply - water withdrawn by public and private water suppliers and delivered to groups of users. Public suppliers provide water for a variety of uses, such as domestic (residential), commercial, industrial, and public water use.
public-supply deliveries - water provided for multiple users through a public-supply distribution system.

public water use - use of water supplied from a public-water supply and used for such purposes as firefighting, street washing, system maintenance, and municipal parks and swimming pools.

recharge (groundwater) - the addition of water to the ground-water system by natural or artificial processes.

reclaimed sewage - wastewater-treatment-plant effluent that has been diverted or intercepted for use before it reaches a natural waterway or aquifer.

recycled water - water that is used more than one time before it returns to the natural hydrologic system.

return flow - water that reaches a ground- or surface-water source, after release from the point of use, and becomes available for further use.

self-supplied water - water withdrawn from a ground- or surface-water source by the water user, rather than being obtained from a public supply.

sewage - waste matter and water that passes through sewers and drains.

sewage treatment - the processing of wastewater for the removal or reduction of solids or other undesirable constituents.

sewage-treatment return flow - water returned to the hydrologic system by sewage treatment facilities.

surface water - an open body of water, such as a stream or a lake.

transpiration - process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface. Also see "evaporation" and "evapotranspiration."

wastewater - water that carries wastes from homes, businesses, and industries.

waterspreading - a system of dams, dikes and ditches or other means of diverting or collecting runoff from natural gullies channels or streams and spreading it over relatively flat areas.

watermaster - State employee who regulates the distribution of water among users of water from any natural surface- or ground-water supply in accordance with the user's existing water rights of record.

water consumed - see "consumptive use"

water rights - legal rights to use a specific quantity of water, on a specific time schedule, at a specific place, and for a specific purpose.

water transfer - artificial conveyance of water from one area to another.

water use - see "offstream use" and "instream use."

withdrawal - water removed from the ground or diverted from a surface-water source for use. Also see "offstream use" and "self-supplied water."

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Appendix A

Umatilla Sub-Basin Task Force Outline

Umatilla Sub Basin Data Synthesis Outline
(Note: All Water Figures in Acre-Feet)

I. General Data (Baseline)

A. Natural Hydraulic System (trying to understand how much water was available naturally in our system) (all figures in acre-feet)

1. Water Supply (Input)
   a) Precipitation and Climactic Records
      i) Total Annual Basin Precipitation

2. Natural Water Consumption
      i) Total Amount of Evapotranspiration
      ii) Total utilized by overland flow and life (native plants, animals,)

3. Natural Surface Water Flows
   a) Source Water in acre-feet (runoff, springs, lakes)
   b) Floodplain acreage (infiltration)
   c) Wetland acreage (infiltration)
   d) Direct Infiltration (loosing reaches)

4. Balance
   - Annual Basin Precipitation
   - – Evapotranspiration
   - – Natural Consumption
   - -Total Surface Water Flow at Mouth of Umatilla River
   - = Amount Supplied to Storage

B. Modified Hydraulic System (trying to understand how much water is available through modifications to the natural system)

1. Water Supply (Input)
   a) Precipitation and Climactic Records
      i) Total Annual Basin Precipitation

2. Water Consumption (Not including irrigation, industry and direct human consumption)
   a) Total Amount of Evapotranspiration
   b) Total Utilized by Life (native plants, dry land agriculture, animals)

3. Modified Surface Water Flows
   a) Source Water in acre-feet (runoff, springs, lakes, reservoirs)
   b) Wetland acreage
      i) number of acres of wetland development
      ii) % change from natural system

c) Floodplain acreage
    i) number of acres of floodplain development
    ii) % change from natural system
d) Channeled water bodies (limits infiltration)
e) Total Diversion
    i) percentage lost to diversion leakage
f) Total Artificial Storage
    i) loss from evaporation

4. Balance
    - Annual Basin Precipitation
    - - Evapotranspiration
    - - Natural and Dry Land Consumption
    - - Total Diversion
    - + percentage lost to leakage
    - + Total Supplied to Artificial Storage
    - - Loss from Evaporation
    - - Total Surface Water Flow at Mouth of Umatilla River
    - = Amount Supplied to Storage

II. Current Consumption Data

A. Irrigated Agriculture

1. Surface Water Consumption (annual)
    a) Total Diversion
    b) – Percentage Loss from Canal Leakage
    c) = Net Annual Consumption

2. Groundwater Consumption
    a) Annual
        i) Extraction
        ii) – recharge/injection
        iii) = Net Annual Consumption

    b) 20 year Total (Net Consumption)

B. Commercial/Industrial/Aggregate (Excludes Water Obtained from City Services)

1. Surface Water Consumption
2. Groundwater Consumption
    a) Annual
    b) 20 Year Total

C. Rural Residential (Exempt Use Only)

1. Basalt Groundwater Consumption (avg. 1.5 acre-feet per year)
2. Alluvial Groundwater Consumption

a) Avg. 1.5 acre-feet per year
b) – Avg. Septic Tank Distribution per year
c) - Avg. Basalt Septic Tank Distribution per year (Total from Dwellings in 1)
d) = Net Alluvial Consumption

D. Urban (Includes Municipal, Industrial and Commercial Uses Utilizing City Services)

1. Surface Water Consumption (Annual)
   a) Total Surface Water Diversion
   b) – Sewage Effluent back to Water Body
   c) + Evaporation
   d) = Net Surface Water Consumption

2. Groundwater Consumption
   a) Extraction
   b) - Recharge/Injection
   c) = Net Groundwater Consumption]
   d) 20 Year Total

E. Consumption Totals and Trends

1) Surface Water Consumption Total
   1) Compare to Flow Needs assessment for Surface Water Quality/Quantity Trend
2) Groundwater Consumption Total
   a) Annual Basalt Total
   b) Annual Alluvial Total
   c) Grand Total

3) Groundwater Trends
   a) Average Annual Increase in Groundwater Extraction
   b) Sustainability (Compare total in (I)(B)(4) with (II)(E)(2))

<u>III Socio-Economic Region Data</u>

A. Fish and Wildlife Region

1. Fisheries
   a) In-stream Flow Needs to Support all Life Stages of Salmonid Species
      i)Spawning
      ii) Rearing
      iii) Migration
   b) Current In-stream Flow Trends
      i) Stable Trends
      ii) Areas of Required Improvement

c) Economic Value of Fisheries
i) Tribal
ii) Commercial
iii) Tourism and Sport fishing
iv) Quality of Life

2. Wildlife
a) Flow and Habitat Requirements
i) Water Quality
ii) Temperature
iii) Habitat Demands
b) Current Trends
i) Stable Trends
ii) Areas of Required Improvement
c) Economic Value of Wildlife
i) Tribal
ii) Tourism and Outdoor Sports
iii) Quality of Life

B. Urban Region (Show Total Existing Demands within Urban Communities)

1. City of Umatilla
a) Current Water Consumption
b) Water Supply and Treatment Infrastructure
c) Permitted Water Supply
i) % of Permitted Water Supply Currently in Use
ii) Permitted Groundwater Total
iii) Permitted Surface Water Total (Sources)
iv) Build-out projection based upon direct supply (No storage facilities)
d) Water Supply Trends
i) Well Depths
ii) Aquifer Trends
iii) Growth Trends
iv) Supply Sustainability with current infrastructure and sources
v) Water Quality
e) Economic Value of Permitted Water Supply

2. City of Hermiston
a) Current Water Consumption
b) Water Supply and Treatment Infrastructure
c) Permitted Water Supply
i) % of Permitted Water Supply Currently in Use
ii) Permitted Groundwater Total
iii) Permitted Surface Water Total (Sources)

iv) Build-out projection based upon direct supply (No storage facilities)

d) Water Supply Trends
   i) Well Depths
   ii) Aquifer Trends
   iii) Growth Trends
   iv) Supply Sustainability with current infrastructure and sources
   v) Water Quality

e) Economic Value of Permitted Water Supply

3. City of Stanfield
   a) Current Water Consumption
   b) Water Supply and Treatment Infrastructure
   c) Permitted Water Supply
      i) % of Permitted Water Supply Currently in Use
      ii) Permitted Groundwater Total
      iii) Permitted Surface Water Total (Sources)
      iv) Build-out projection based upon direct supply (No storage facilities)
   d) Water Supply Trends
      i) Well Depths
      ii) Aquifer Trends
      iii) Growth Trends
      iv) Supply Sustainability with current infrastructure and sources
      v) Water Quality
   e) Economic Value of Permitted Water Supply

4. City of Echo
   a) Current Water Consumption
   b) Water Supply and Treatment Infrastructure
   c) Permitted Water Supply
      i) % of Permitted Water Supply Currently in Use
      ii) Permitted Groundwater Total
      iii) Permitted Surface Water Total (Sources)
      iv) Build-out projection based upon direct supply (No storage facilities)
   d) Water Supply Trends
      i) Well Depths
      ii) Aquifer Trends
      iii) Growth Trends
      iv) Supply Sustainability with current infrastructure and sources
      v) Water Quality
   e) Economic Value of Permitted Water Supply

5. City of Pendleton
   a) Current Water Consumption

b) Water Supply and Treatment Infrastructure
c) Permitted Water Supply
i) % of Permitted Water Supply Currently in Use
ii) Permitted Groundwater Total
iii) Permitted Surface Water Total (Sources)
iv) Build-out projection based upon direct supply (No storage facilities)
d) Water Supply Trends
i) Well Depths
ii) Aquifer Trends
iii) Growth Trends
iv) Supply Sustainability with current infrastructure and sources
v) Water Quality
e) Economic Value of Permitted Water Supply

6. City of Pilot Rock
a) Current Water Consumption
b) Water Supply and Treatment Infrastructure
c) Permitted Water Supply
i) % of Permitted Water Supply Currently in Use
ii) Permitted Groundwater Total
iii) Permitted Surface Water Total (Sources)
iv) Build-out projection based upon direct supply (No storage facilities)
d) Water Supply Trends
i) Well Depths
ii) Aquifer Trends
iii) Growth Trends
iv) Supply Sustainability with current infrastructure and sources
v) Water Quality
e) Economic Value of Permitted Water Supply

7. Mission Community
a) Current Water Consumption
b) Water Supply and Treatment Infrastructure
c) Permitted Water Supply
i) % of Permitted Water Supply Currently in Use
ii) Permitted Groundwater Total
iii) Permitted Surface Water Total (Sources)
iv) Build-out projection based upon direct supply (No storage facilities)
d) Water Supply Trends
i) Well Depths
ii) Aquifer Trends
iii) Growth Trends
iv) Supply Sustainability with current infrastructure and sources

        v) Water Quality
    e) Economic Value of Permitted Water Supply

8. City of Adams
    a) Current Water Consumption
    b) Water Supply and Treatment Infrastructure
    c) Permitted Water Supply
        i) % of Permitted Water Supply Currently in Use
        ii) Permitted Groundwater Total
        iii) Permitted Surface Water Total (Sources)
        iv) Build-out projection based upon direct supply (No storage facilities)
    d) Water Supply Trends
        i) Well Depths
        ii) Aquifer Trends
        iii) Growth Trends
        iv) Supply Sustainability with current infrastructure and sources
        v) Water Quality
    e) Economic Value of Permitted Water Supply

9. City of Helix
    a) Current Water Consumption
    b) Water Supply and Treatment Infrastructure
    c) Permitted Water Supply
        i) % of Permitted Water Supply Currently in Use
        ii) Permitted Groundwater Total
        iii) Permitted Surface Water Total (Sources)
        iv) Build-out projection based upon direct supply (No storage facilities)
    d) Water Supply Trends
        i) Well Depths
        ii) Aquifer Trends
        iii) Growth Trends
        iv) Supply Sustainability with current infrastructure and sources
        v) Water Quality
    e) Economic Value of Permitted Water Supply

10. City of Athena
    a) Current Water Consumption
    b) Water Supply and Treatment Infrastructure
    c) Permitted Water Supply
        i) % of Permitted Water Supply Currently in Use
        ii) Permitted Groundwater Total
        iii) Permitted Surface Water Total (Sources)
        iv) Build-out projection based upon direct supply (No storage facilities)

d) Water Supply Trends
    i) Well Depths
    ii) Aquifer Trends
    iii) Growth Trends
    iv) Supply Sustainability with current infrastructure and sources
    v) Water Quality
e) Economic Value of Permitted Water Supply

11. Urban Region Trends
  a) Total Permit Demand
    i) Ground
    ii) Surface
  b) Status
    i) Total Developed
    ii) Total Undeveloped
    iii) Grand Total
    iv) Sustainability (Compare total in (III)(B)(11) (a) with (II)(E)(2))
    v) Source Availability
      - Contour Map

C. Irrigated Agricultural Region

1. Surface Water
  a) Source (Supply) Waters and Annual
  b) Current Consumption
  c) Total Permit Demand
  d) Compare Supply Vs. Demand

2. Groundwater
  a) Current Consumption (Agricultural + Exempt Uses)
  b) Current Recharge/Injection
  c) Total Permit Demand
  d) Sustainability (Compare total in (III)(C)(2) (c) with (II)(E)(2))

3. Economic Value of Irrigated Agricultural Region Water
  a) Land Value
  b) Product Value

D. Dryland (Unirrigated) Agricultural Region

1. Total Ag Water Demand
2. Total Exempt Demand
3. Grand Total
4. Sustainability (Compare total in (III)(D)(3) with (II)(E)(2))
5. Economic Value of Dryland Region

E. Forest Region

1. Total Exempt Water Demand
2. Hydraulic Importance
   a) Water Purification
   b) Water Storage
      i) Recharge
      ii) Surface Storage
   c) Net Storage Total
      i) Total Precipitation
      ii) – Evaporation and plant use
      iii) – Exempt Use
      iv) – Run-off
      v) = Total Net Storage
3. Economic Value of Forest Region

<u>IV. Basin Status</u>

A. Surface Water

1. Total Instream Flow Needs
   a) Total Needed to meet insteam need
   b) Total Currently reserved for Instream Use
   c) Balance unallocated for Insteam demands

2. Total Surface Water Right Permit Demand
   a) Active Water Rights
   b) Inactive (junior) Water Rights

3. Balance

B. Groundwater

1. Total Natural and Groundwater Storage (Annual)

2. Total Groundwater Right Permit Demand
   a) Active Water Rights
   b) Inactive (junior) Water Rights

3. Total Exempt Well Demand (1.5 acre-feet per year per well)

4. Balance

C. Amount of Potential Storage Utilizing Existing Unperfected Columbia River Water Rights

1. Figure Zero Consumption, Total Storage

D. Balance Total

V. Applicable Water Laws

A. Federal

1. ESA
2. Warren Act
3. Etc.

B. State

1. Legislative (ORS)
2. Administrative (OAR)

Appendix B

Umatilla Water Resources Chronology

Umatilla Basin Water Chronology

This historical chronology describes critical events and decisions that have impacted water usage in the Umatilla Basin since 1855. The chronology was prepared by water historian Dr. Catherine Howells.

Resources consulted include, but were not limited to:

- Oregon Water Resources Department (OWRD)
- Oregon Department of Fish and Wildlife (ODFW)
- Oregon Department of Environmental Quality (ODEQ)
- Oregon Land Conservation and Development Commission (LCDC)
- Umatilla County Planning Department
- Umatilla County Critical Groundwater Solutions Task Force documents
- Confederated Tribes of the Umatilla Indian Reservation (CTUIR) Department of Natural Resources
- US Bureau of Reclamation (BoR)
- United States Geological Survey (USGS)
- National Marine Fisheries Service (NMFS)
- United States Environmental Protection Agency (USEPA)
- United States Department of Agriculture (USDA)
- Northwest Power and Conservation Council (NWPCC)

UMATILLA BASIN CHRONOLOGY

1855 Treaty with the Walla Walla, Cayuse and Umatilla Tribes and the United States government -- treaty reserved rights for tribes to hunt, fish and gather traditional foods

1859 Treaty ratified by Congress

1862 Umatilla County created by state legislature

1862 Irrigation begins in Umatilla County

1864 City of Umatilla incorporated

1880 City of Pendleton incorporated

1880-1920 population increase

1882 Union Pacific Railroad arrives

1890 Umatilla Meadows and Butter Creek Canal Company organized to enlarge and extend ditch diverting water from Umatilla River to irrigate land across the river from Echo -- becomes Hinkle Ditch Company

1893 Intention of Water Use (first State of Oregon water allocation law)

1903 Bureau of Reclamation (BoR) begins investigations to determine feasibility of irrigating lands around the Umatilla River

1903 Gaging station established on Umatilla River -- two miles upstream from mouth of the river

1903 Hinkle Ditch Company begins irrigating land south and east of Hermiston by diverting water from Umatilla River

1905 Furnish Ditch Company begins construction of system to irrigate several thousand acres near Stanfield by diverting water from Umatilla River

1906 BoR construction of projects begins after Congressional approval

1907 City of Hermiston incorporated

1908 Winters v. United States (legal basis for reserved water rights for tribes)

1908 Hermiston Irrigation District created

1908 Cold Springs Dam and Reservoir, Feed Canal Diversion Dam and Feed Canal completed -- to supply supplemental irrigation water to the Hermiston Irrigation District

1909 Furnish Dam completed

1910 First Pendleton Round-Up

1912 Maxwell Diversion Dam completed

1913-17 Three Mile Falls Diversion Dam and West Extension Main Canal built to provide water to West Extension Irrigation District

1916 Adjudicated decree of water rights to use waters of Umatilla River and its tributaries (1953 supplemental findings and order of determination identified inchoate rights to be allowed)

1917 West Extension Irrigation District created

1920 - 1940 Population and economic decline (summer water shortages and soils unsuited for irrigation). Decline in irrigated acreage continued until 1949, when trend reversed

1925 First well (125 feet) in Butter Creek area

1926 State fish and wildlife experts report that there were no chinook or coho left in the Umatilla River

1927 McKay Dam and Reservoir completed -- to supplement water supplies for Stanfield and Westland Irrigation Districts

1938 Bonneville Dam completed

1940 BoR Pendleton Project initiated

1940 - 2000 Population increase due to Federal projects (Umatilla Depot, McNary Dam construction) and manufacturing/processing plants

1941 Umatilla Military Reservation established. Operated as onsite explosive washout plant from 1950s to 1965

1949 - 1959 Alfalfa production increases 45% (more irrigated alfalfa and less non-irrigated hayland)

1950s Irrigation from groundwater begins

1951 BoR report on McNary Gravity Investigation concluded to no irrigation facilities were required in McNary Dam and recommended additional study of potential irrigation development areas in the Plymouth Bench area

1952 First deep well (554 feet) in Butter Creek Area (deepened to 840 feet in 1961)

1954 Pendleton Project Investigation by BoR. Identified several plans for storage and utilization of surplus Umatilla River waters. Concluded that potential irrigable land far exceeded available water supply. No plans were financially feasible in terms of full repayments of reimbursable costs within 40 years (report released locally as an information document to aid local planning)

1955 Oregon Groundwater Act: No water rights needed for stockwatering, irrigating lawns or non-commerical gardens of 1/2 acre, for single or group domestic purposes not exceeding 15,000 gallons per day , or for single industrial or commercial purpose not to exceed 5,000 gallons per day

1958 First reports of water table decline in Butter Creek area

1959 BoR determines available water storage based on adjudicated rights and permits on the Umatilla River

1960 Groundwater level monitoring begins in Butter Creek area

1960s Groundwater levels dropping in Battle Creek

1963 BoR report on possible Birch Creek Diversion Unit -- reanalyzed canal plan and concluded construction still unwarranted

1963 OWRD produces map showing location of 480 sub-basin water rights; reports on scarcity of groundwater and minimal recharge

1963 OWRD reports that fish life will probably take an increasing non-consumptive use of water in the Umatilla River

1963 ODFW conducts survey of steelhead and Chinook spawning habitat on the upper Umatilla River

1964 Based on local and state concerns, BoR begins study to provide comprehensive analysis of multiple-purpose development potential on basin- wide scale (results published in 1970)

1964 Oregon Water Resources Commission adopts Umatilla Basin program

1966 Groundwater use for center pivot irrigation begins

1966 Congressional authorization for Secretary of the Interior to conduct feasibility investigation to expand irrigation base and address anadromous fishery needs in the Umatilla Basin

1969 BoR constructs pumping plant on Columbia River to lift water into West Extension Canal

1970 BoR reports that any significant increase in pumping from basalt aquifers would likely result in accelerated decline of water tables

1972 72 irrigation wells in Butter Creek area (depth 665-1500 feet)

1972 Federal Clean Water Act

1973 Oregon Senate Bill 100 signed by Governor McCall. Creates Oregon statewide planning program with the Land Conservation and Development Commission (LCDC) and the Department of Land Conservation and Development (DLCD).

1974 Oregon LCDC adopts 14 statewide planning goals

1974 Eastern Central Oregon Association of Counties completes Regional Water System Feasibility Study for Hermiston-Boardman, Oregon

1975 Port of Umatilla proposes a regional water system based on their permit for the project of 155 cfs from the Columbia River

1976 OWRD designates Butter Creek a Critical Groundwater Area (remanded until 1986)

1976 Critical Groundwater Area designated by OWRD for Ordnance Basalt

1976 Critical Groundwater Area designated by OWRD for Ordnance Gravel

1977 Lost Lake/Depot well owners initiated project to artificially recharge shallow gravel aquifer using existing canal system

1980 CTUIR initiates Umatilla Salmon Recovery Project

1980 ODFW initiates a steelhead supplementation program

1980s Coalition formed between CTUIR and local irrigators to recover salmon populations -- BoR, BPA, OWRD and ODFW participate

1980 ODFW begins hatchery-outplanting program on Umatilla River to supplement natural production

1983+ Umatilla County Comprehensive Plan recognizes that availability of water is a key resource for economic growth

1983 ODFW and ODEQ submit minimum stream flow requirements for Umatilla Basin to State Water Resources Board

1984 Umatilla Chemical Depot placed on EPA's National Priorities List because of soil and groundwater contamination

1984 Formation of Umatilla Basin Project Steering Committee

1985 Umatilla River and tributaries withdrawn from further appropriation by Oregon Water Resources Commission and minimal perennial stream flows adopted by Umatilla River and Birch Creek

1985 Umatilla Basin Fish Resource Improvement Committee (UBFRIC) adopts plan. Developed in cooperation with CTUIR, ODFW, National Marine Fisheries Service, Fish and Wildlife Service, BoR and Forest Service (funding for plan from BPA)

1986 Critical Groundwater Area designated by OWRD for Buttercreek Basalt

1986 Report to the Governor, Umatilla Basin Ground Water Task Force (identifies water use concerns and suggests alternatives)

1987 Oregon Instream Water Rights Act -- recognizes in-stream uses as beneficial

1988 Umatilla Basin Project authorized and funded by Congress (developed by CTUIR and irrigators coalition -- allows irrigators to exchange Umatilla River water for Columbia River water)

1988 Oregon Water Resources Commission approves Oregon Water Plan: Umatilla Basin Sections

1989 Oregon Groundwater Quality Protection Act

1990 Classified Groundwater Area designated by OWRD for Ella Butte (exempt uses only)

1990 ODEQ declares 352,000 acres in Umatilla and Morrow counties as a groundwater management area (GWMA) after discovering elevated levels of nitrates in wells -- leads to the Lower Umatilla Basin GWMA Voluntary Plan

1991 Critical Groundwater Area designated by OWRD for Stage Gulch Basalt

1991 OWRD enforces compliance against waterspreading

1992 Oregon DEQ and EPA conduct sampling to characterize regional groundwater quality -- Lower Umatilla Basin identified as area of elevated nitrate in groundwater

1994 Salmon return to the Umatilla River (first time in seventy years)

1995 Columbia River Intertribal Fish Commission (CRITFC) develops anadromous fish restoration plan for Columbia River Basin

1997 Oregon Plan for Salmon and Watersheds

2003 Umatilla County ranked fifth in state in agricultural commodity sales at $200 million

2003 Oregon Water Resources Department report published -- Ground Water Supplies in the Umatilla Basin

2003 Aquifer Storage and Recovery (ASR) Pilot Testing in for City of Pendleton

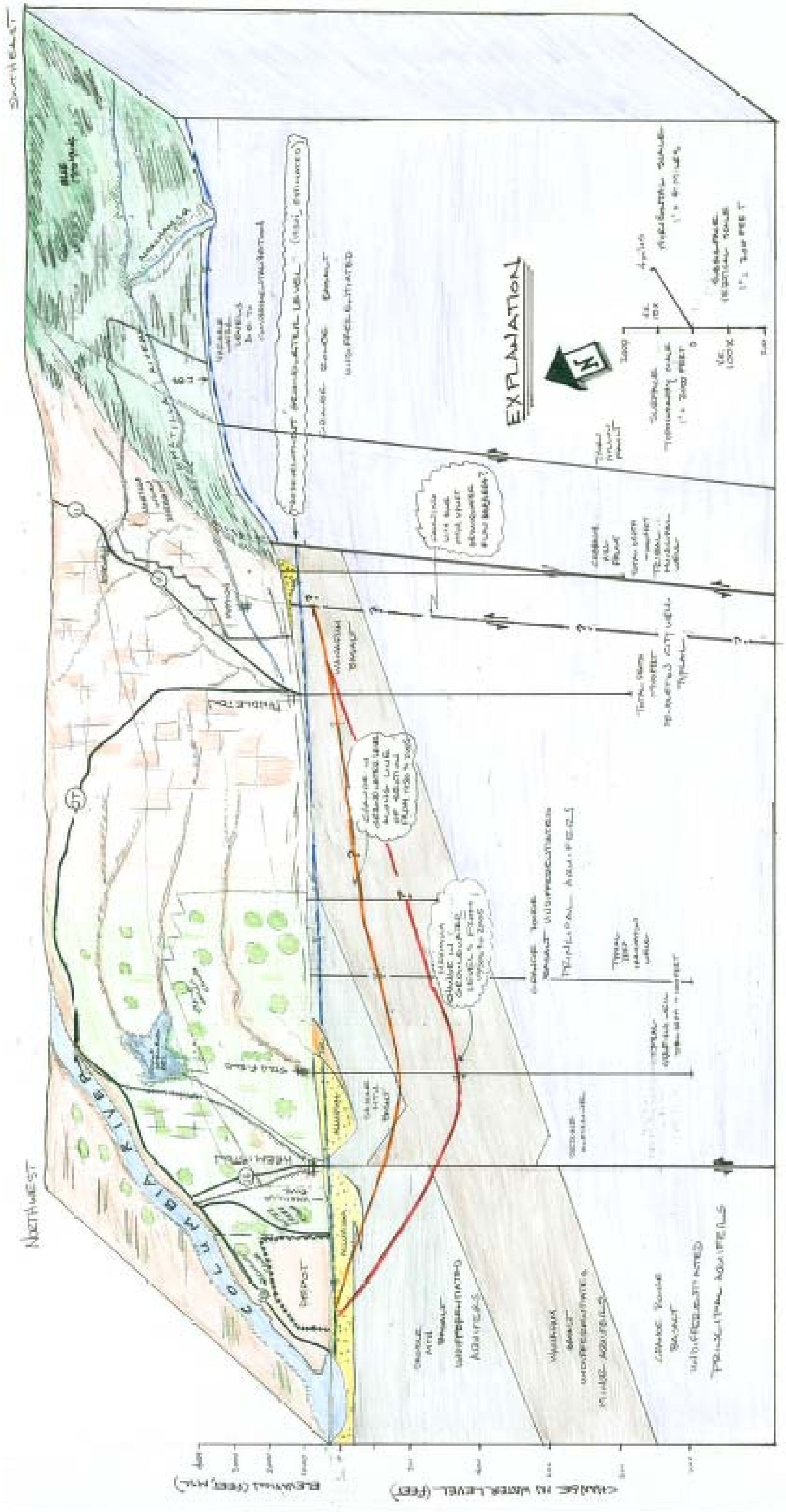
2004 Umatilla County Critical Groundwater Task Force created by the Umatilla County Board of Commissioners in order to develop a “2050 Plan” to assure adequate groundwater for broad community needs through the year 2050

2004 Northwest Power and Conservation Council (NWPCC) adopts Umatilla Sub-basin Plan

2005 Board of Commissioners of Umatilla County adopt Exempt Well Resolution until 2050 plan is authorized

Appendix C

Concept Hydrogeologic Model
Of the Umatilla Sub-Basin


NORTHWEST
SOUTHEAST
EXPLANATION
COLUMBIA RIVER
PENDLETON
HERMISTON

Appendix D

Potentiometric Surface Maps

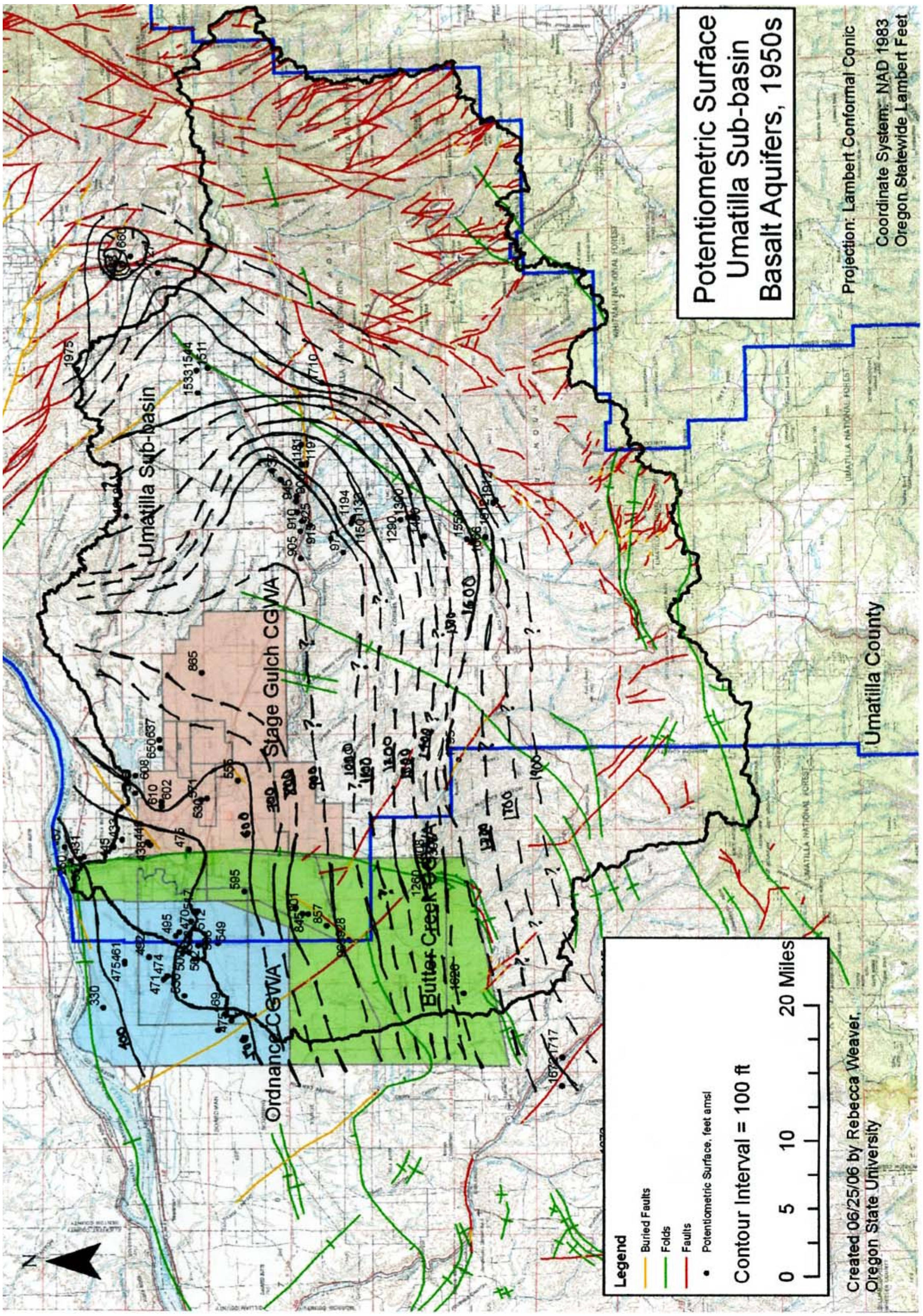
Umatilla Sub-Basin Potentiometric Surface Maps: Data Sources and Processing

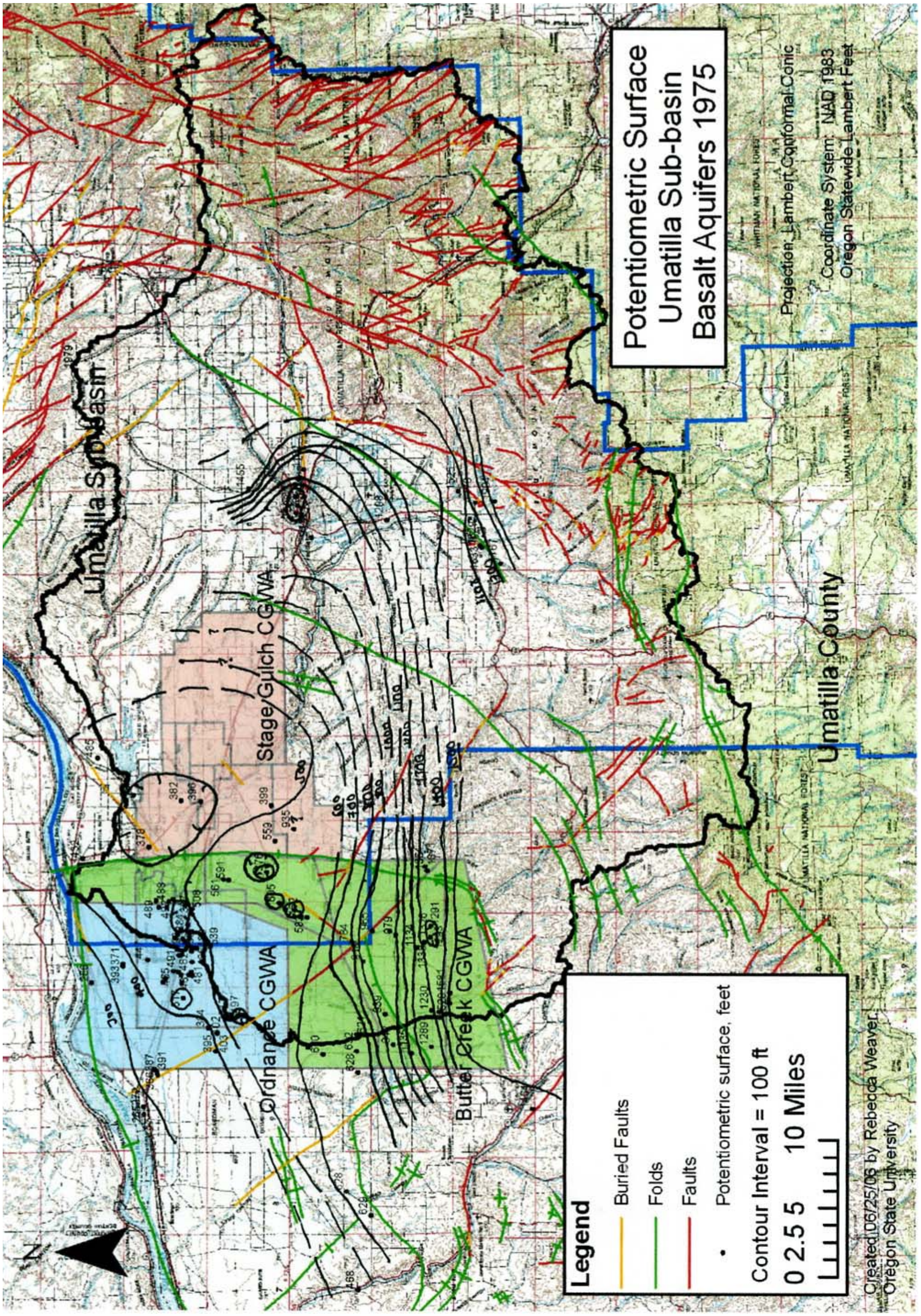
Groundwater level data were gathered from datasets publicly available on the Oregon Water Resources Department website. The 1975 and 2005 data sets were refined to include only measurements taken during the winter of those years, when groundwater levels are most recovered from the low precipitation and irrigation pumping of the summer. These data points range from December through March, but when more than one measurement had been taken from a well during this period, the measurement in or closest to the month of February was chosen. The rationale for this choice was to group the data as closely as possible around the OWRD synoptic sampling events, which occur annually in that month and were the source of the majority of the data.

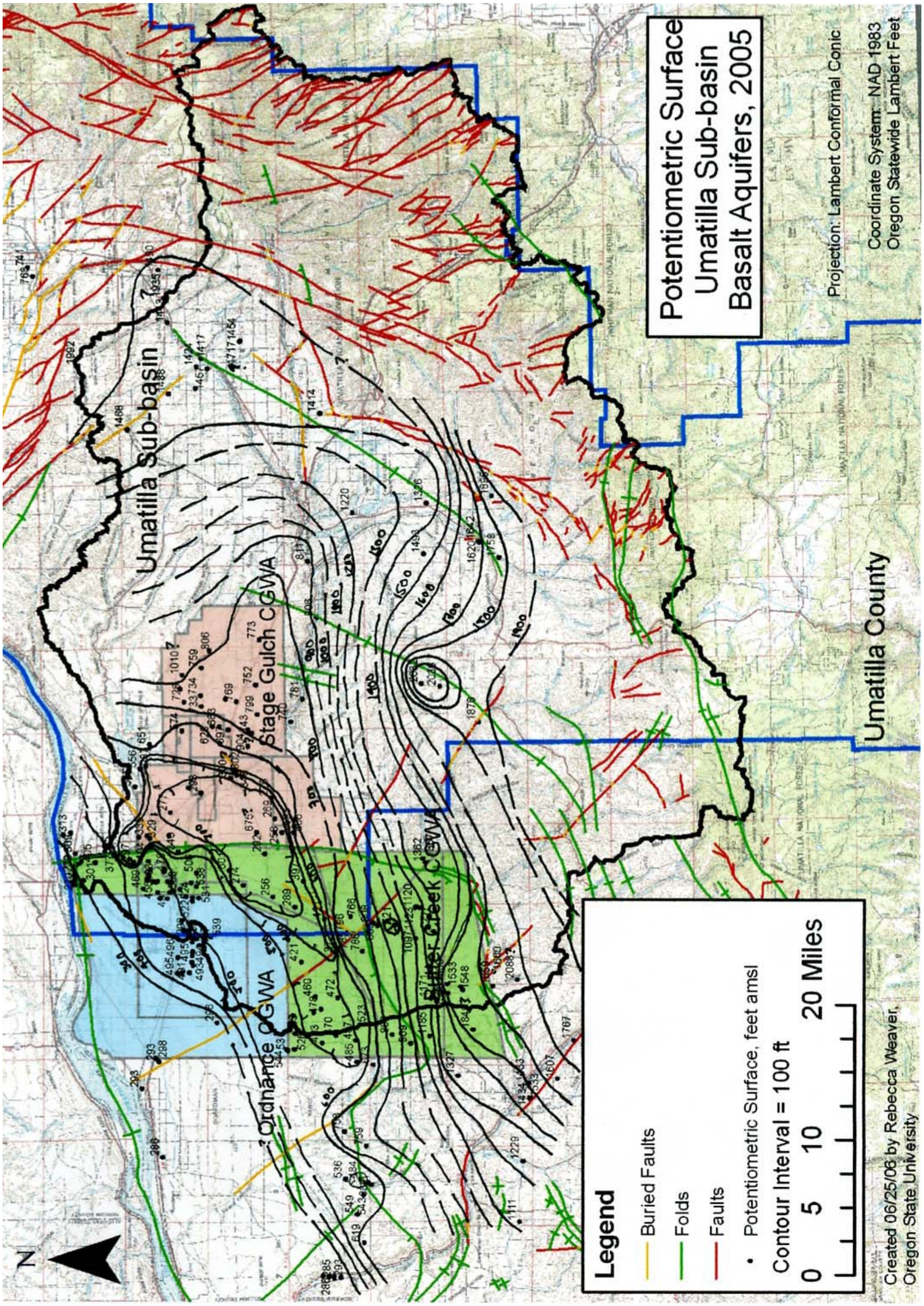
Because water level data were sparse for the 1950s, data points from any month or year of this decade were used to create a composite 1950s groundwater level contour map. Where more than one measurement on a well existed for this time period, the earliest was chosen, as the purpose of this map was to establish conditions prior to the extensive development of groundwater in the region. This approach yielded a coherent contour map. For the maps showing change in groundwater elevation, data were used only from wells that had been sampled both in 1975 and 2005 and in the 1950s and 2005.

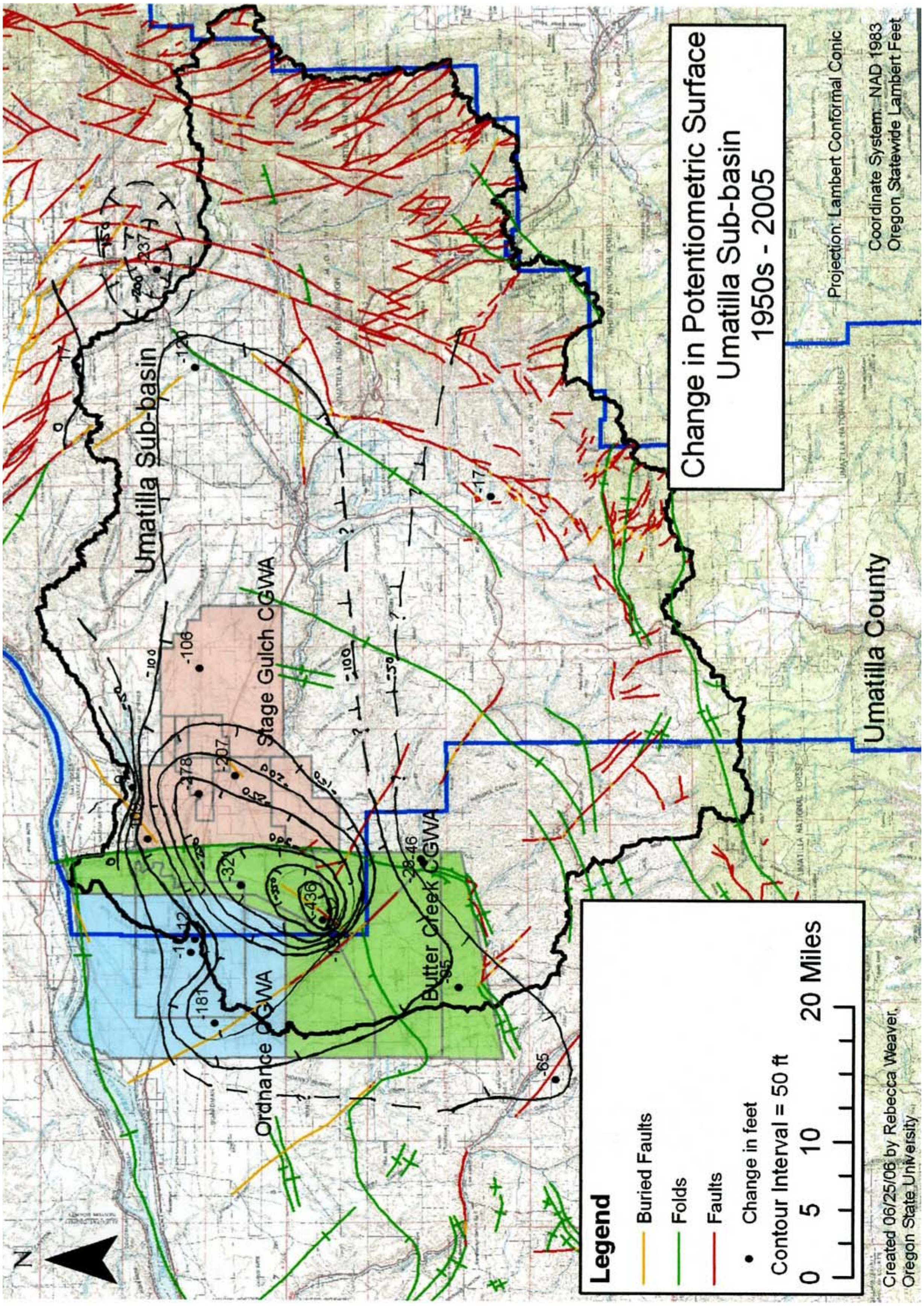
Groundwater level data were rounded to the nearest foot and compiled with latitude and longitude measurements for each well into a 3-dimensional data set. These data points were added to a map of the Umatilla Sub-basin in ArcGIS 9. Well locations were displayed with groundwater elevation labeled, and potentiometric surface contours were hand-drawn based on these plots.

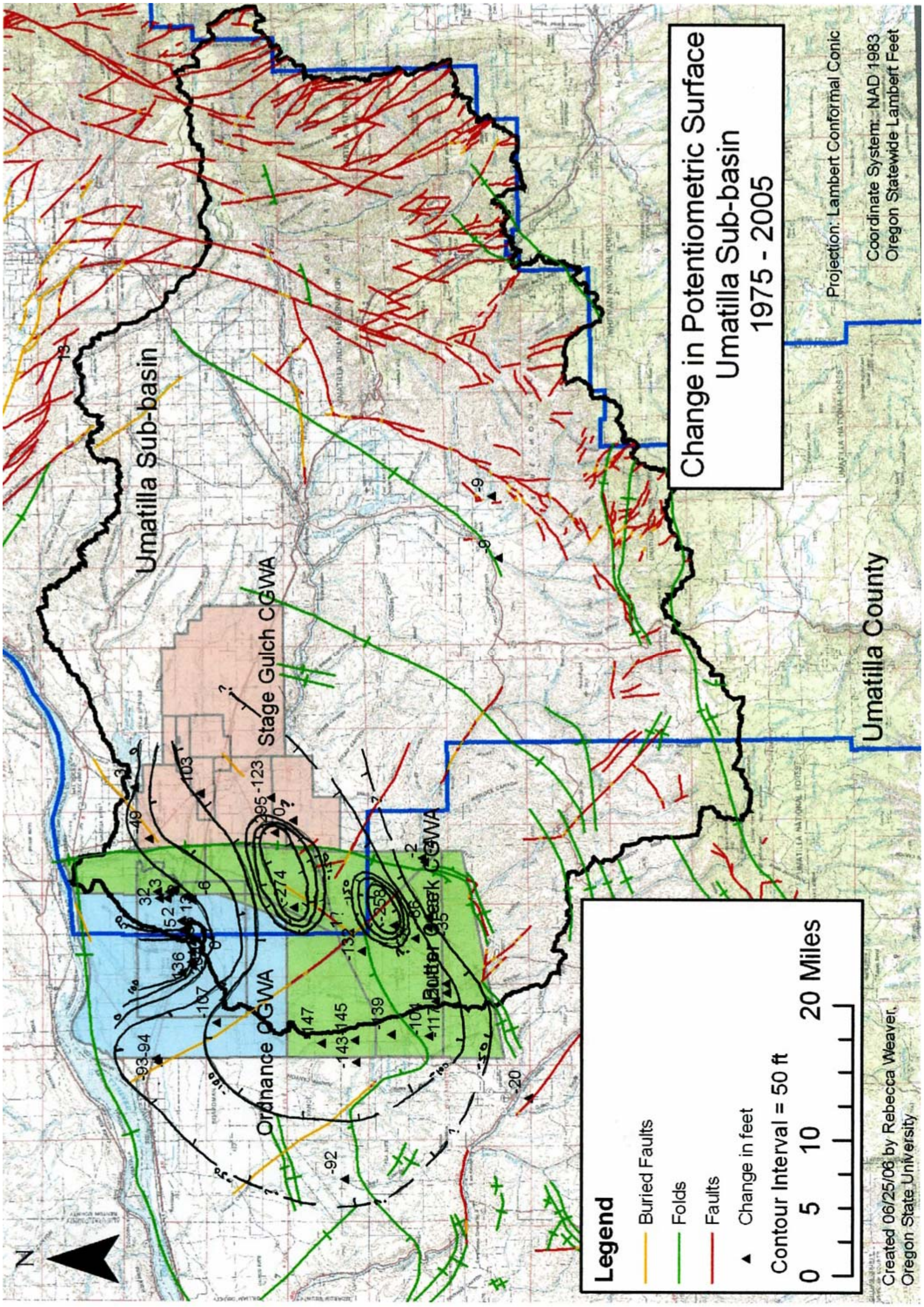
Some areas of the maps are contoured with dashed lines or question marks to indicate greater levels of uncertainty. It is important to note that even the areas that are contoured with solid lines are interpreted, and the nature of the data cautions against considering any area on the map as absolutely accurate. The geology of the Umatilla region is such that each well is likely to intercept more than one interflow zone between basalt layers, so that even a single water level measurement is a composite of pressures at several different depths. Viewed at the regional scale, however, it is hoped that these maps will prove useful to an understanding of groundwater declines in the Umatilla Sub-basin over the past 50 years.


Potentiometric Surface
Umatilla Sub-basin
Basalt Aquifers, 1950s
Projection: Lambert Conformal Conic
Coordinate System: NAD 1983
Oregon Statewide Lambert Feet
Umatilla Sub-basin
Stage Gulch CGWA
Butter Creek CGWA
Ordnance CGWA
Umatilla County
N
Legend
Buried Faults
Folds
Faults
Potentiometric Surface, feet amsl
Contour Interval = 100 ft
0 5 10 20 Miles
Created 06/25/06 by Rebecca Weaver,
Oregon State University


Potentiometric Surface
Umatilla Sub-basin
Basalt Aquifers 1975
Projection: Lambert Conformal Conic
Coordinate System: NAD 1983
Oregon Statewide Lambert Feet
Umatilla Sub-basin
Umatilla County
Stage Gulch CGWA
Ordnance CGWA
Butter Creek CGWA
N
Legend
Buried Faults
Folds
Faults
Potentiometric surface, feet
Contour Interval = 100 ft
0 2.5 5 10 Miles
Created 06/25/06 by Rebecca Weaver,
Oregon State University


Potentiometric Surface
Umatilla Sub-basin
Basalt Aquifers, 2005
Projection: Lambert Conformal Conic
Coordinate System: NAD 1983
Oregon Statewide Lambert Feet
Umatilla Sub-basin
Stage Gulch CGWA
Ordnance CGWA
Butter Creek CGWA
Umatilla County
N
Legend
Buried Faults
Folds
Faults
Potentiometric Surface, feet amsl
Contour Interval = 100 ft
0 5 10 20 Miles
Created 06/25/06 by Rebecca Weaver,
Oregon State University


Change in Potentiometric Surface
Umatilla Sub-basin
1950s - 2005
Umatilla Sub-basin
Stage Gulch CGWA
Butter Creek CGWA
Ordnance CGWA
Umatilla County
-106
-207
-278
-321
-436
-181
-120
-17
-65
Legend
Buried Faults
Folds
Faults
Change in feet
Contour Interval = 50 ft
0 5 10 20 Miles
N
Created 06/25/06 by Rebecca Weaver, Oregon State University
Projection: Lambert Conformal Conic
Coordinate System: NAD 1983 Oregon Statewide Lambert Feet


Change in Potentiometric Surface
Umatilla Sub-basin
1975 - 2005
Projection: Lambert Conformal Conic
Coordinate System: NAD 1983
Oregon Statewide Lambert Feet
Umatilla Sub-basin
Stage Gulch CGWA
Ordnance CGWA
Butter Creek CGWA
Umatilla County
Legend
Buried Faults
Folds
Faults
Change in feet
Contour Interval = 50 ft
0 5 10 20 Miles
Created 06/25/06 by Rebecca Weaver,
Oregon State University

Appendix E

Wastewater as Groundwater Recharge:
Is Toilet to Tap a Fair Characterization?

Wastewater as Groundwater Recharge

Is from Toilet to Tap a Fair Characterization?

Authors (OSU WRP 599 Technical Group Members)

Scott English ***Malia Kupillas*** ***Jay Zarnetske***

The Issue

The question has been raised about whether the use of the phrase **"Toilet to Tap"** is a fair characterization of the process that uses treated wastewater to recharge groundwater. The answer is, No. Wastewater does not go directly from the toilet to the tap. Wastewater can be treated through a multi-step process that can produce water, which meets or exceeds drinking water standards. Thus, treated wastewater has the potential to serve as an important source of water for groundwater recharge. This is important, because non-potable wastewater is the only source of water that increases as our population and demand for potable water increases. Global freshwater resources are becoming increasingly stressed, especially in areas experiencing drought, urban growth, or shifting agricultural practices, which has resulted in the development of aquifer storage and recovery projects (ASR). ASR projects have increased dramatically in response to groundwater depletions, and have become a viable alternative to constructing more dams and reservoirs. ASR provides a cost effective way to store water for peak demands, or recharge an aquifer, with less of an impact on the environment. However, the sources of water available to use for ASR are limited, while wastewater production continues to increase. Therefore, an integrated solution for providing adequate groundwater recharge and proper disposal of wastewater consists of using treated wastewater as a groundwater recharge source. This solution is tenable as innovative water treatment and distribution technologies continue to improve. Still major barriers such as public perception, technology, economics, and public safety must be overcome prior to its implementation on a global scale.

The History

Technically, **all water is reused on a global scale due to the hydrologic water cycle.** For years municipalities have obtained their water upstream and discharged their treated wastewater downstream. Depending on the hydrology of the stream, that surface water has the potential to become groundwater. An example of wastewater re-use is the Thames River. On the Thames River, an average of 12 percent of the water used for public water supply comes from indirect effluent re-use. During a dry summer, the percentage can increase to 70 percent, locally[29]. A portion of that surface water may have been stored as groundwater. Thus, we all live downstream.

Domestic septic systems have been used for a long time, and the water from those systems eventually recharges the groundwater. In some areas, high nitrate levels are a problem in the groundwater because the travel time from the septic system to the aquifer is too short, and the density of septic systems are too high.

Treated wastewater has been used in California and Texas to stop saltwater intrusion by injecting the treated water into the aquifer, which forms a barrier to the movement of saltwater[30].

The general public is not aware of the above history of using treated wastewater for recharging groundwater. They do not realize that each watershed receives wastes from everything that lives there, not just humans, and that water eventually recharges aquifers. The people of Los Angeles do not realize that the water they receive from the Colorado River has received water from septic tanks and sewage treatment systems upstream, and the water arrives in Los Angeles with the same quality as tertiary-treated wastewater[31].

Public Perception

What role does public perception play?

The concept of using treated wastewater as groundwater recharge has existed for nearly 60-years. However, recently the public's perception and their acceptance or rejections of the use of treated wastewater has controlled the fate of the project. The three little words "toilet to tap" in a newspaper's headlines in 2000 doomed Los Angeles' plans to used treated wastewater to recharge an aquifer[32]. Thus, research began to better understand the publics perception of using wastewater for groundwater recharge, and how to overcome their "yuck" factor[33].

- Now it is recognized that public perceptions and acceptance of wastewater reuse are the first and most important components for a successful beneficial reuse project from the social perspective after the technical feasibility has been established. Presently, research indicates that the greatest disconnect between public perception and the reality of the practice is the result of inadequate efforts to make the public aware of the complete wastewater reuse process. For example, the "toilet to tap" concept in the United States persists only if the general public is not made aware of the extensive wastewater treatment processes carried out between the toilet and tap (Figure 1). Furthermore, successful wastewater reuse

[29] WaterWare, 2006
[30] Aravinthan, Vasantha
[31] Waldie, D.J., 2002
[32] Waldie, D.J., 2002
[33] Dingfelder, S.F. 2004

projects from around the world have emphasized public involvement throughout the design and implementation process, and utilized adaptive management practices to meet the changing needs of the public.

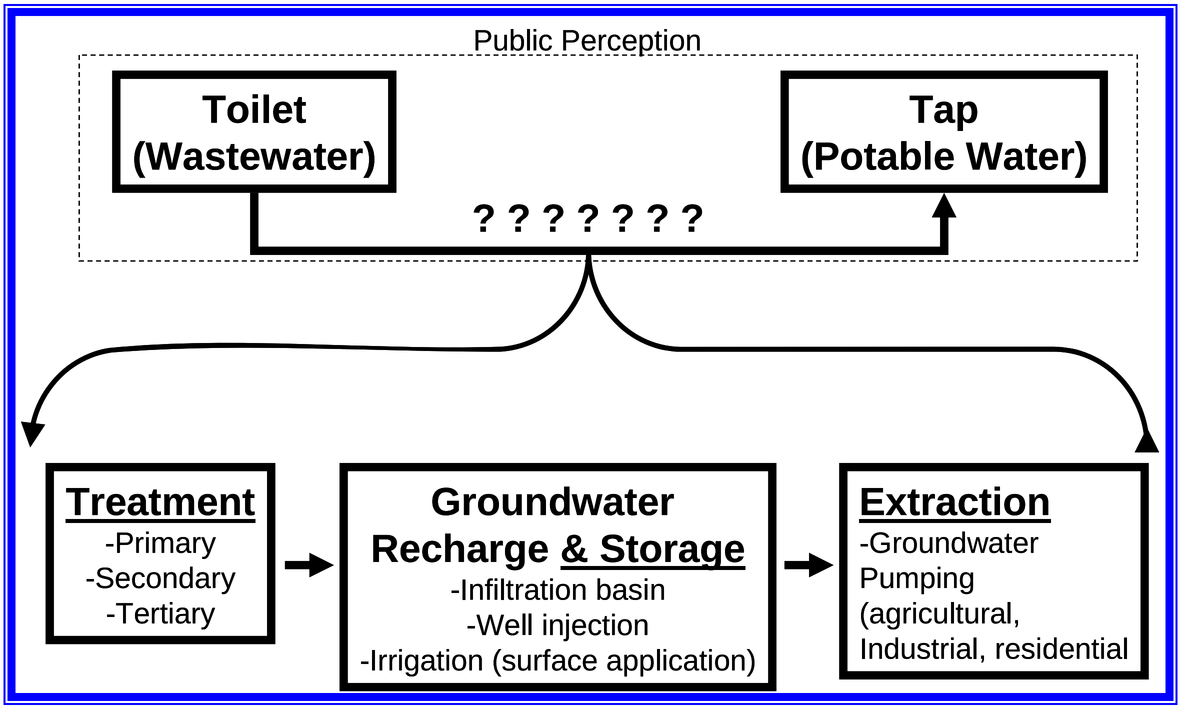


Figure 1. General scheme of the processes involved using wastewater as groundwater recharge ***Note the components included in the general public perception of the practice (components inside dashed box).***

Despite obvious benefits, why is the public reluctant to accept the practice?

- Prior efforts and limited research indicate that there are many factors including:
  - The "yuck" factor, which represents the human emotion or perception of disgust for coming into contact with wastewater in any way, shape, or form.
  - Uncertainty associated with the potential risks of using recycled wastewater.
  - Not being adequately involved and/or informed in wastewater reuse project planning, which results in a sense of powerlessness and consequently distrust of the project.
  - The cost associated with the project implementation, maintenance, and operation.
  - The project planner's motivation for the project is perceived as insincere.
  - Socio-demographic factors, such as different age groups yielding greater resistance/acceptance toward the practice.

- Additional research looking into the role of each of these factors in the public perception process is needed.

How can the Public's Aversion to Using Reclaimed Water Be Overcome?

- Studies have shown that interjecting an extra step or two into the wastewater treatment process allows people to create a mental barrier to the history of the water, which allows them to ignore potential contamination[34]

- Mental barriers can also be created by linking treated wastewater with an environmental organization. Today's wastewater must be treated to a level that it does not negatively impact the environment. That same level of treatment produces the same quality of water that can be used for groundwater recharge. Therefore, what is good for the environment is good for recharge.

- The economic benefits must also be emphasized, which targets a person's tendency to minimize risk when the benefit is seen as a positive. For example, a person who loves rock climbing will tend to minimize the sport's dangers while they are climbing. This minimization of the dangers is achieved through experience, training, and following proper safety procedures.

- The most important aspect of addressing the public's concerns is through proper education about the technological aspects of wastewater treatment, the quality of water that is generated from that process, and how the treated wastewater is applied for recharge to groundwater

Technological Aspects of Wastewater Treatment

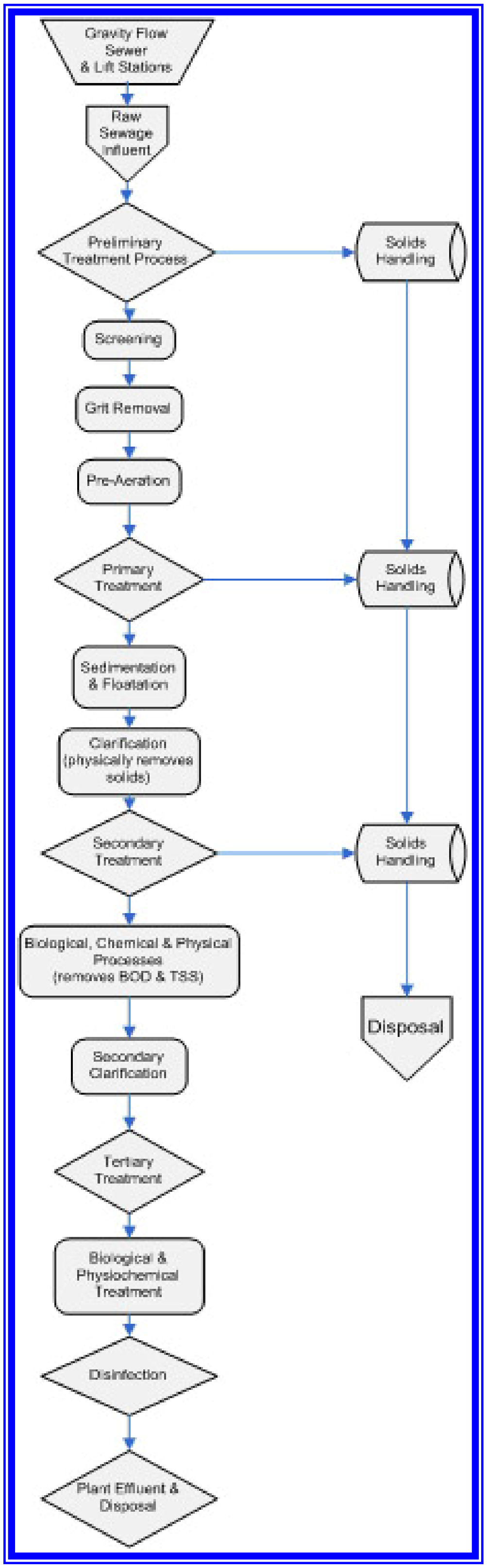
What are the technical methods available for treating wastewater to meet drinking water standards?

- Wastewater is generated through domestic septic systems and two main urban sources (a) municipal and (b) industrial. To some extent wastewater has been used to recharge groundwater for years.

- On a small residential scale, septic systems are used to discharge wastewater, which eventually filters downward and becomes groundwater. The type of soil present, local concentration of septic systems, soil chemistry, and depth to groundwater affect the ability of the wastewater to be treated naturally in this manner.

- On a larger scale, and usually associated with larger urban centers, wastewater is collected and treated at centralized municipal facilities rather than septic systems.

[34] Dingfelder, 2004



Treated municipal wastewater is frequently discharged into the nearby receiving stream. The treated wastewater mixes with the surface water and travels downstream where the next municipality obtains their drinking water from the stream.

- There are generally two main sources of urban wastewater generation: municipal and industrial. Municipal wastewater is generated from domestic sources such as toilets, showers, washing machines, and other household related activities. On the other hand, industrial wastewater is generated by commercial, industrial or nonresidential activity. Companies and institutions that use water during manufacturing, remediation, cleaning or rinsing processes often generate industrial wastewater.

- Currently, in most countries of the developed world, Figure 2 illustrates a valid generalization of the municipal wastewater treatment process. It is important to realize that the primary objective of the municipal wastewater treatment is to remove biochemical oxygen demand (BOD), total suspended solids (TSS), and pathogenic bacteria.

Figure 2. Typical Municipal Wastewater Treatment Process.

- Note that in many of the developing countries the secondary and tertiary treatment processes are omitted due to economic constraints. Also the marginally treated wastewater is often considered to be a valuable asset for direct reuse as surface irrigation due to its high nutrient content. A prolonged practice of irrigation in this manner may have a significant effect on the groundwater recharge and the groundwater quality. Again the soil type, the proximity of wells, and level of well water production are all major factors on the quality of the aquifer in this situation.

- It is quite common for industrial wastewater to be discharged into municipal wastewater collections and treatment systems. For this reason, many wastewater managers have established an industrial waste program for local industries that discharge into the municipal sewers. Guidelines and routine monitoring are established to insure that discharges will not harm workers or disrupt treatment plant operations. Specialized staff is often employed to assist local industries to prevent pollution practices. For example *hazardous waste* is any substance that is toxic, explosive, flammable, corrosive, or reactive and these substances may not be discharged into the wastewater collections system. Additionally, many industries are required to provide some form of pretreatment onsite to remove specific substances and pollutants from the waste stream prior to discharging to the municipal sewer. The biggest threat to the contamination of the aquifer and public health may be associated with the industrial wastewater component. Yet the public perceives the "toilet to tap" as the biggest threat.

- For communities that desire to use the urban wastewater effluent for groundwater recharge it is especially important that the details of both the municipal and the industrial influent sources are well understood and adequately managed. The following are some of the specific concerns regarding urban wastewater being considered for groundwater recharge. Pathogenic bacteria and viruses are common in urban wastewater effluent that lacks adequate treatment and disinfection and can contaminate a native aquifer. High levels of nitrogen in the form of nitrate (NO_3) and ammonical-nitogen (NH_4) are common in under-treated wastewater (i.e., those lacking secondary treatment). Dissolved organic carbons (DOCs) are often associated with the formation of persistent trihalomethanes (THMs) that develop in the disinfection process of potable water. Fortunately, existing ASR projects have shown that THM's breakdown in groundwater and are not a problem. Also associated with the DOCs are potentially toxic and highly persistent organic pollutants (POPs) such as phthalates, sterols, phenols, PCBs along with other organic chemicals considered to be carcinogenic compounds and endocrine disrupters[35]. Nickle and arsenic and other toxic heavy metals are often found in industrial waste streams.

- Basic groundwater chemistry may impact carbonate and redox reactions within the aquifer and the potential reducing conditions may release nickel and arsenic from dissolution of manganese and iron oxides[36]. However, these potential issues are a part of the initial hydrogeologic investigation that examines potential geochemical reactions between the groundwater and wastewater.

[35] Foster, 2003
[36] BGS Technical Report WC/98/39

An important message is to realize that industrial wastewater is often very difficult to characterize at an individual level, and complex toxic substances are often formed with the commingling of wastes from other sources. Many forms of industrial pollutants are often toxic in very low concentrations such that detection is both difficult and expensive. However, these issues can be overcome by managing industrial wastewater before it is discharged into a municipal system before injection begins.

The greatest rate of change in aquifer quality occurs in aquifers with a low specific yield, where turnover is relatively rapid and the rate of internal cycling is high. In this situation deterioration of the groundwater can occur rapidly (i.e., 1 to 2-decades). So for those communities considering the use of urban wastewater for groundwater recharge the best management practice is to work closely with the local industrial waste generators to minimize the practices that generate toxic pollutants, to consider reuse methods that reduce discharge pollutants through higher in-plant efficiency, to evaluate alternative methods that may reduce the need for highly toxic substances all together, and to develop effective and economical pretreatment methods that are tailored to the pollutants being generated thus removing them before they are discharged into the municipal system.

Technological Aspects of Groundwater Recharge

How is wastewater used as groundwater recharge?

- The indirect and direct use of treated wastewater have been identified as a cost effective way to recharge aquifers and meet growing water needs. Treated wastewater can be used in three different ways to recharge groundwater (Figure 3). First, treated wastewater recharges shallow unconfined aquifers, when it is used for irrigation, especially flood irrigation. Second, treated wastewater can be discharged into infiltration galleries, where it can slowly move down through the soils to reach the aquifer. Third, treated wastewater can be injected directly into an aquifer through injection wells where in can be stored for later use. An additional benefit of this injection method is that it can be used to limit salt water intrusion in coastal urban regions where groundwater usage exceeds natural recharge, thus contaminating the aquifer with salinity from the ocean. Since the injected recharge water is less dense than the saltwater they remain segregated in the aquifer.

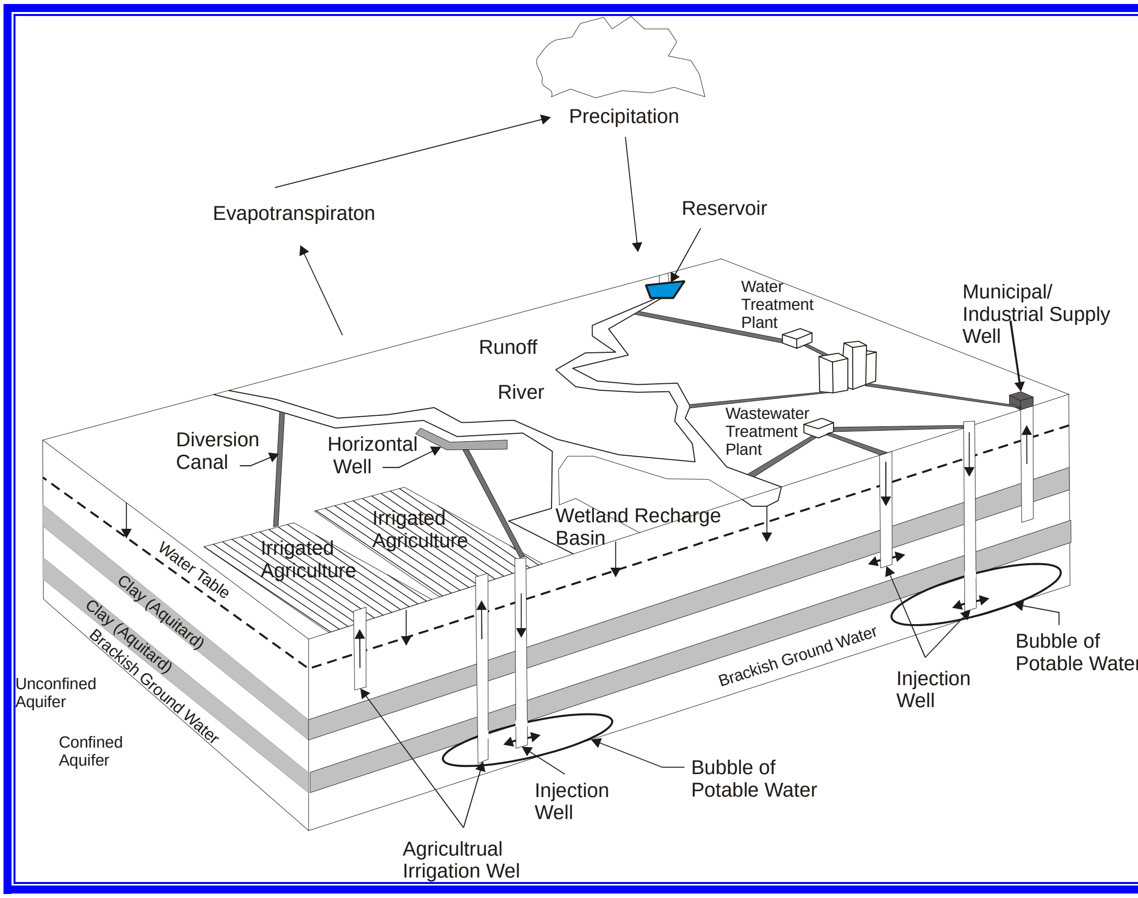


Figure 3. The hydrologic cycle with wastewater recharge to groundwater.

- The level of treatment required can vary with the type of application. The use of treated wastewater for irrigation and discharge into infiltration galleries requires at least primary treatment. The direct injection of treated wastewater requires either secondary or tertiary treatment. The ability of the aquifer to remove additional contaminants, and the proximity of the nearest groundwater user should determine the level of treatment necessary before direct injection into groundwater. Thus, each project must be designed to meet drinking water standards, when the treated wastewater is intended to be used as drinking water. The fact that the treatment of wastewater is basically accelerating the natural process of water purification by dilution and bacterial processes should be kept in mind.

- In addition, injected groundwater is further treated by natural processes. For example, water-borne pathogens are naturally attenuated after injection. Studies have also shown that low levels of nitrates can also be attenuated through dilution and de-nitrification after the wastewater has been injected. Thus, there are additional water treatment benefits after the wastewater has been injected.

Future Trends and Uncertainty

The 2003 World Water Development Report prepared for the United Nations indicates that more than 50 percent of the nations in the world will be coping with water shortages by 2025. That figure potentially increases to 70 percent by 2050[37].

Who are the international trend setters with this practice?

- Treated wastewater has been reused for several decades in nonpotable applications, and indirectly recharged to aquifers that provide drinking water[38]. As water needs increase and substantial shortages begin to occur, then the use of treated wastewater will become an important water resource both in the United States and internationally. For example, Texas is predicting that 20 to 34 percent of their future water supplies will come from wastewater reuse by 2050[39].

- A few of the international trend setters are Australia, Singapore, Orange County, California, Arizona, and Texas,

- Singapore's NEWater plant, which uses reclaimed water, avoided the public outrage that occurred in Los Angeles. This plant was designed by CH2MHIll, who continues to emphasize the benefits of using reclaimed (treated wastewater). They overcame the psychological barriers by injecting the treated water into natural reservoirs, and they call the water NEWater, in contrast to reclaimed wastewater[40].

In practice, can public perception and wastewater reuse coexist?

- The Singapore NEWater reclaimed water project avoided the public distrust and anger that has accompanied nearly all other similar efforts, especially those located in the United States. The NeWwater facility, which supplies Singapore with more than 3 million gallons of drinking water per day, implemented an award-winning public information campaign prior to its construction. Through the use of public interest polling, the project was able to tap into the public perception surrounding the project. The NEWater group broadcasted the benefits of the project such as its importance of to the country's continued economic success, and also acknowledged that a new water source could significantly decrease Singapore's dependence on nearby Malaysia's freshwater sources, something very favorable to the public. By highlighting the benefits, the public was less focused on their concerns. Furthermore, a visitor's center was incorporated into the plant, which continues to emphasize the benefits of reclaimed water.

[37] United Nations. 2003.
[38] Chapman, Ginette.
[39] Hightower, M. et al
[40] Dingfelder

- This project also overcame the psychological barriers to reclaimed water (i.e. the “yuck” factor) by injecting the treated water into natural reservoirs, which made the water's origins less conspicuous and, consequently, of less concern to the public. Additionally, measures such as calling the water “NEWater,” as opposed to “reused” or “reclaimed wastewater,” helped the public distance themselves from the origin of the water.

Key Facts

- **The hydrologic cycle shows all water is reused water.**
- **Water needs are going to increase as populations increase and wastewater is one source of water that increases with population growth.**
- **Using treated wastewater to recharge groundwater is one viable option to making our water resources more sustainable.**
- **The technology for using wastewater recharge is currently available.**
- **Surface water dams create their own ecological/environmental impact, and most of the suitable sites have already been developed.**
- **The public needs to be involved at the initial planning stages.**
- **The public concern needs to be technically addressed at each step of the process.**
- **Additional research into the limitations and the consequences of using wastewater for recharge needs to be performed.**
- **Working closely with industrial waste generators who discharge to municipal sewers can reduce much of the uncertainty of reuse water quality, and can ultimately prove to be one of the most cost effective best management approaches.**

Key Questions

- **What politics will evolve around who is going to be responsible for supervising, managing, and operating the quality control of the wastewater reuse?**
- **What are the legal uncertainties that will impede the process of using treated wastewater for groundwater recharge?**
- **Which international institutions should provide oversight and have the greatest authority over wastewater management?**
- **Who is at greatest risk for inappropriate implementation?**

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