Steve Sisolak
Governor

Richard Whitley, MS
Director

DEPARTMENT OF HEALTH AND HUMAN SERVICES

DIVISION OF PUBLIC AND BEHAVIORAL HEALTH

Helping people. It's who we are and what we do.

Lisa Sherych
Administrator

Ihsan Azzam,
Ph.D., M.D.
Chief Medical Officer

NOTICE OF PUBLIC HEARING

THE CARSON CITY HOLDING LLC IS REQUESTING A VARIANCE, #721, FROM THE NEVADA STATE BOARD OF HEALTH REGULATIONS.

NOTICE IS HEREBY GIVEN that the CARSON CITY HOLDING LLC has requested a variance from Nevada Revised Statues (NRS) 444.178.

A public hearing will be conducted on December 3rd, 2021, at 9:00 am by the Nevada State Board of Health to consider this request. This meeting will be held online.

Meeting Locations:

Join from computer using the Zoom meeting link:

https://zoom.us/j/91711965467?pwd=WDc0MWJUVnZGRC85VEp1QnNUUExlZz09

Online Conference ID Number: 917 1196 5467
Passcode: 422977

Join by Phone:
1-669-900-9128 (San Jose) Access Code: 917 1196 5467
Passcode: 422977
Phone Conference ID Number: 439 309 712#

The CARSON CITY HOLDING LLC is requesting a variance from NRS 444.178 which states:

NRS 444.178 Disinfectants: Approval of use of chemical feeders and other disinfecting materials and methods. (NRS 439.200, 444.070)

1. A public bathing or swimming facility must be equipped with a chlorinator, hypochlorinator or other disinfectant feeder. Except as otherwise provided in subsections 2 and 3, chemical feeders and process equipment, other than compressed chlorine gas feeders, must be designated by the NSF International as complying with all applicable requirements of Standard 50, "Circulation System Components and Related Materials for Swimming Pools, Spas/Hot Tubs," of the NSF International or in the absence of applicable requirements, be approved by the health authority. A copy of this standard may be obtained from the NSF International, P.O. Box 130140, Ann Arbor, Michigan 48113, at a cost of $45.

2. The health authority may approve other feeders if the operator of the facility demonstrates to the health authority that the required residual concentrations of disinfectant can be maintained using the feeder.

3. Chemical feeders must be capable of supplying not less than the equivalent of 3 pounds (1.4 kilograms) of chlorine for outdoor pools, or 1 pound (454 grams) of chlorine in the case of an indoor facility, per 10,000 gallons (37,850 liters) of facility capacity during a 24-hour period.

4. The health authority may approve other disinfecting materials or methods if the operator of the facility demonstrates to the satisfaction of the health authority that they provide a satisfactory residual effect which is easily measured and are as effective at disinfecting as the use of the chlorine concentrations required in NAC 444.148.

5. Disinfectant feeders must be installed to ensure that the flow of the chemical disinfectant will stop immediately if there is an interruption in the flow of water to the pool or through the disinfection system.

[Bd. of Health, Public Bathing Places Reg. Art. 29, §§ 29.1-29.1.2, eff. 5-21-74] — (NAC A 9-17-82; 11-1-88; 1-16-96)

The authority of the State Board of Health to consider and grant a variance from the requirements of a regulation is set forth at NRS 439.200 and NAC 439.200 – 439.280.

Persons wishing to comment upon the proposed variance may appear at the scheduled public hearing or may submit written testimony at least five days before the scheduled hearing to:

Secretary, State Board of Health
Division of Public and Behavioral Health
4150 Technology Way, Suite 300
Carson City, NV 89706

Anyone wishing to testify for more than five minutes on the proposed variance must petition the Board of Health at the above address. Petitions shall contain the following: 1) a concise statement of the subject(s) on which the petitioner will present testimony; 2) the estimated time for the petitioner's presentation.

This notice has also been posted at the following locations:

DIVISION OF PUBLIC AND BEHAVIORAL HEALTH, 4150 TECHNOLOGY WAY, CARSON CITY, NV

DIVISION OF PUBLIC AND BEHAVIORAL HEALTH WEBSITE:
http://dpbh.nv.gov/Boards/BOH/Meetings/Meetings/

NEVADA STATE BOARD OF HEALTH
NEVADA STATE HEALTH DIVISION
4150 Technology Way, Suite 300
CARSON CITY, NV 89706

APPLICATION FOR VARIANCE

Please check the appropriate box that pertains to the NAC for which you are requesting a variance.

☐ Division Administration (NAC 439, 441A, 452, 453A, & 629)

☐ Child, Family & Community Wellness (NAC 392, 394, 432A, 439, 441A, & 442)

☐ Health Care Quality & Compliance (NAC 449, 457, 459 & 652)

☐ Health Statistics, Planning, Epidemiology and Response (NAC 440,450B, 452, 453, 453A, & 695C)

☒ Public Health & Clinical Services (NAC 211, 444, 446, 447, 583, & 585)

Date: August 1, 2021

Name of Applicant: Carson City Holding LLC Phone: 907-229-1465

Mailing Address: 445 East 5th , Suite 201

City: Anchorage State: Alaska Zip: 99504

We do hereby apply for a variance to chapter/section 444.178 of the Nevada Administrative Code (NAC). (For example: NAC 449.204)

Title of section in question: Disinfectants

Statement of existing or proposed conditions in violation of the NAC:

Last year the Nevada State Board of Health granted our facility, Historic Carson Hot Springs a variance to NAC 444.178 (1). The variance gave us the ability to have flow-through for all the pools, spas and Jacuzzies we have at the facility. The variance we received gave us a six-hour turnover rate. This was a rate we were suggesting based on history. Now that we are operating all the pools and we see how the flow is working we now requesting to amend the portion of the

variance that references the turn-over rate. We would like to have the turnover rate of the water to the pools, spas and jacuzzies to be adjusted to every twelve hours, instead every six hours. The real preference is no regulated turnover rate, like most states, but I am not sure your ability to grant us that variance.

Date of initial operation (if existing):	**The original pool and mini spas have been operating since the mid 1800's. We took over ownership in 1998 and have operated under our standards since then. Additional new pools and jacuzzies are complete and have been operating since mid-January 2021**

ATTENTION: Please read this section closely. Your request for variance will be examined against these criteria:

Any person who, because of unique circumstances, is unduly burdened by a regulation of the State Board of Health and thereby suffers a hardship and the abridgement of a substantial property right may apply for a variance from a regulation. (NAC 439.200(1))

1. The State Board of Health will grant a variance from a regulation only if it finds from the evidence presented at the hearing that:
   (a) There are circumstances or conditions which:
      (1) Are unique to the applicant;
      (2) Do not generally affect other persons subject to the regulation;
      (3) Make compliance with the regulation unduly burdensome; and
      (4) Cause a hardship to and abridge a substantial property right of the applicant; and
   (b) Granting the variance:
      (1) Is necessary to render substantial justice to the applicant and enable him to preserve and enjoy his property; and
      (2) Will not be detrimental or pose a danger to public health and safety.

2. Whenever an applicant for a variance alleges that he suffers or will suffer economic hardship by complying with the regulation, he must submit evidence demonstrating the costs of his compliance with the regulation. The Board will consider the evidence and determine whether those costs are unreasonable.
   (NAC 439.240)

Therefore, it is important for your variance request to be as complete as possible. It is your responsibility to attach documentation supportive of your variance request.

Statement of degree of risk of health:

We believe based on our years of operating the Historic Carson Hot Springs first with the original pool and spas and now new additional pools and jacuzzies that the health risk is very low or not at all if the flow-rate was adjusted. We also base this statement on the fact we operate Hot Springs in

Jemez, New Mexico where there are no turn-over rate requirements. The Jemez Hot Springs have been operating since 1860's and have had no health issue that we are aware of. Based on how we have been operating and past owners have operated Historic Carson Hot Springs for decades we have not seen or experienced any health issues. We now have two outside pools, nine mini spas/soaking tubs and two large jacuzzies. As you are aware there are no rules for flow-through type pools under state law. All our pools, spas and jacuzzies are flow-through system (used in many hot springs around the country). We open at 7:00am and close 10:00pm every day. The water enters the pool from one end and drained on the other end. The water flows through the pools, spa and jacuzzies all day long and then on a regular basis they are drained and sanitized. In doing this the water is constantly moving like a river. We use this system to keep the water clean and temperature controlled. This system and how the water turn-over has been used since the pool was constructed in the mid 1800's. We test the water throughout the day as a normal procedure as well as checking the temperature. The water is tested for city purposes once a month and inspected by the city every month., as well las spot checks We have attached several past reports that will show no issues with our water or how we manage it.

Please state in detail the circumstances or conditions which demonstrate that:

1. An exceptional and undue hardship results from a strict application of the Regulation:

We are a small operation, that over the years we have remodeled the facility utilizing cash from the business. The existing pools along with our new additions have been a huge benefit to our customers and the surrounding area. We have also changed the rules so people can only stay for a few hours at a time, rather than the old all-day experience they had before.

The reason people come to our facility is for the quality of the water, the "pure sweet water" (no sulfur or chemical smell or chemicals added). This is what makes our Hot Springs unique compared to so many others. We have people that come from the local area, as well as from around the country. As an example, during the holiday season for about three weeks we have 2 to 3 buses a day from San Francisco that come full of customers to use the springs. The reason they come and bypass other springs in California is our water is "pure sweet water". About 20% of our business and growing comes from these types of out-of-state visitors who are looking for the experience. It is critical we have more flexibility to manage the flow to naturally control the temperatures of the pools, spas and jacuzzies. The first reason is safety. We use the water flow to set the temperature of each water feature and if the waterflow is too fast (which brings in the hot water) and the

outside is too hot, then the pool becomes too hot and people are unable to go into it, because it could exceed the temperature limits, 104 degrees. We then must close that pool while it cools down. Getting a pool that size to cool down is very time consuming and has a direct impact to our revenue stream. We can mix city water into the pool to cool it down, but this becomes very expensive, we found just trying that for a three-week period cost additional amount of over $6,000 for the water bill. On an annual basis this will exceed $100,000 a year in new expense, not counting the waste of the city water. I have attached the water bill for that period and the two previous months so you can see the increase. The second reason is the type of meters that are required to monitor the flow at a six-hour level are not cheap, they can run around $750 each installed. We have had to install 13 of these just to monitor the flow. Since March two have already failed. The reason they fail is because the water is too hot, and the meters are designed for cold water and finding hot water ones are almost impossible. Having the flexibility to manage the flow rates will ensure the ability to protect the health and safety or our customers through regulating water temperatures by the flow of the water. To ensure we do this correctly, we have installed automated temperature controls to ensure that the flow can be done at the right times and maintain the levels we need to keep the temperature in the safe zone. In the past this was done by hand. Now that we are automated, we can see certain times of the day we need to a have a different flow rate to maintain the correct temperatures. This additional information we did not have when we requested six-hour turn-over rate. This new information has made it clear we need to be in that 12-hour turn-over rate. Remember even with that turn-over rate the water is still flowing through the pool, just slower. There are times when we will increase the flow rate to heat the pools back up to the correct temperature.

Adding these additional pools and the upgrades that were required by the city to the property in the middle of Covid has been a challenge and expensive. We exceed our budget mainly due to a direct result of Covid, which caused limited workforce, restricted work times and material cost increase. This is not your issue, but I wanted to point this out as we are a small operation, and we are trying to limit the negative economic impacts to our business and the additional flow requirements are one of those negative impacts we are trying eliminate or reduce.

Any financial relief will help us keep the pool profitable as well as keep the experience that the customer has enjoyed for over 160 years. Everything we can do to keep it in its historical use helps maintain the historic experience.

One other note, because our water is not treated with chemicals the water is used to hydrate the wetlands down from us that the government owns.

States that I have reviewed and I operate in other than Nevada that have flow-through style, have eliminated the need for regulations as the water flows through and therefore it does accumulate the bacteria as stagnate pools would. New Mexico no longer regulates the flow-through style pool. Montana requires by law a minimum of 8-hour turnover rate. Colorado, Wyoming and Utah have no rules around turn-over rate but have standards around temperature (I have attached a spread sheet with references on this research).

2. The variance, if granted, would <u>not:</u>
   A. Cause substantial detriment to the public welfare.

No, it would not. For all the reasons stated above. We have shown since we have operated the pools, spas and jacuzzies as a flow-through system with the correct maintenance, monitoring and safety we can protect the public welfare. If our water has any issues, it will damage our business reputation, which in turn costs money. So, we are not interested in creating an unhealthy or unsafe environment for our customers. The water is the core of our business. Customers demand the quality we provide.

   B. Impair substantially the purpose of the regulation from which the application seeks a variance.

No, it will not impair substantially the purpose of the regulation. As the regulation that you have in place makes sense for pools and jacuzzi's that use filter and recirculation systems for the water. That type of water needs to be treated as it is the recirculated water. A flow-through system dumps the water it uses on an on-going basis and never recirculates the same water and the pools, spas and jacuzzies are drained and sanitized on a regular basis. During this period of COVID-19 and before there has been no cases of virus or spread of other types of illness by our current operation. Additionally during Covid-19 there have been no reported outbreaks by the members of the Hot Springs Business and Trade Association. The Association represents a wide range of Hot Spring Operators across the country.

The bureau may require the following supporting documents to be submitted with and as a part of this application:

X 1. Legal description of property concerned — **APN 008-123-39 1500 Old Hot Springs Rd., Carson City, NV 89706**

See attachment for legal description

X 2. General area identification map

X 3. Plat map showing locations of all pertinent items and appurtenances

N/A 4. Well log (if applicable)

X 5. Applicable lab reports

N/A 6. Applicable engineering or construction/remodeling information

X 7. Other items (see following pages)

This application must be accompanied by evidence demonstrating the costs of your compliance with regulations or specific statutory standards. Your request will be placed on the Board of Health agenda 40 days or more after receipt in this office if accompanied by the required fee (NAC 439.210). The application and supporting documentation will form the basis for the Health Division staff report and recommendation to the Board. Failure to respond to the above statements may cause the Board to deny consideration of the application at the requested Board meeting.

Please schedule this hearing as:

☒ The next regularly scheduled Board of Health meeting, regardless of location.

☐ The next scheduled meeting in Carson City.

☐ The next scheduled meeting in Las Vegas.

Signature: [signature]

Printed Name: Mark Begich

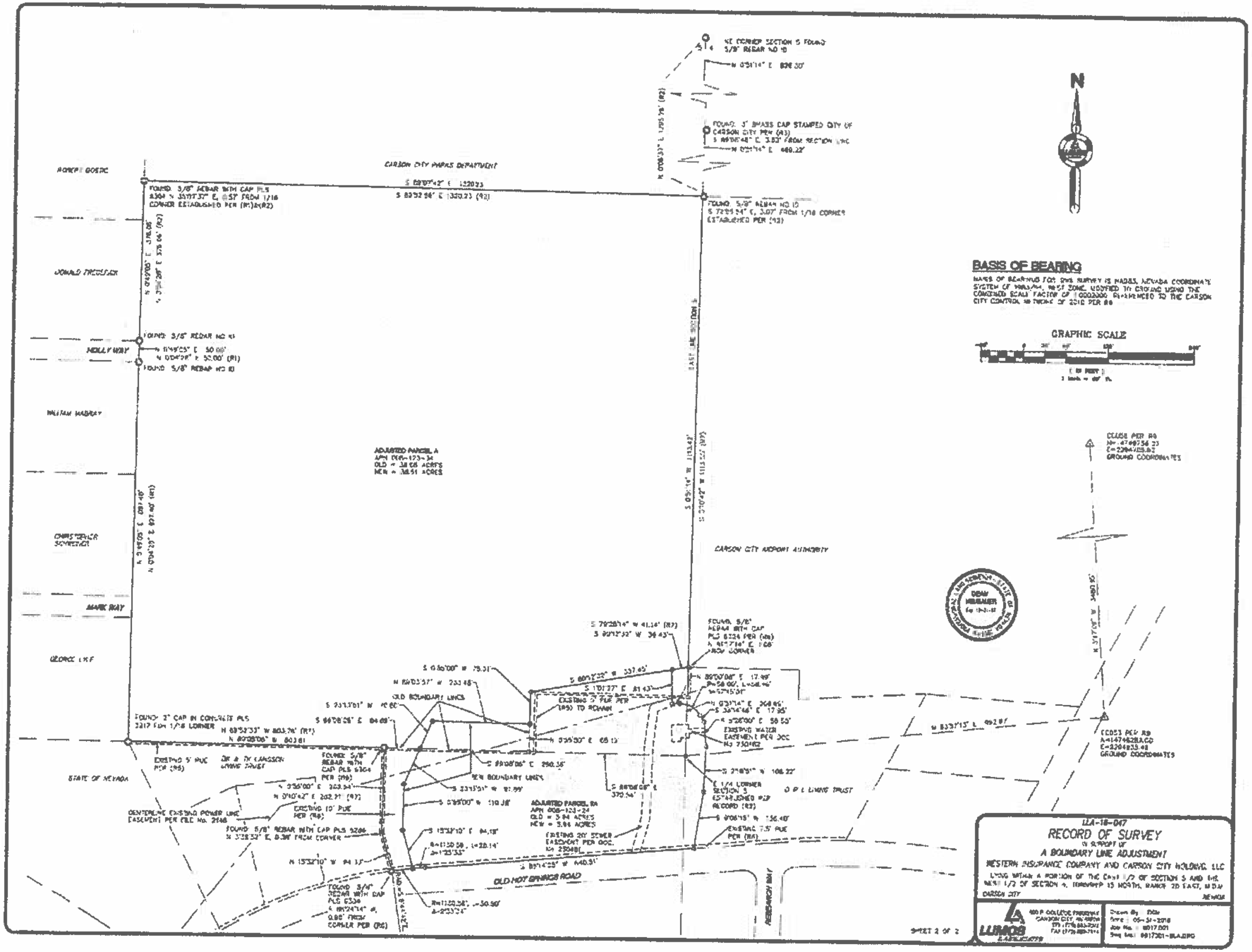
Title: Managing Partner

Date: 8 · 3 · 2021

PLEASE MAKE YOUR CHECK OR MONEY ORDER PAYABLE TO: NEVADA STATE HEALTH DIVISION AND RETURN THIS APPLICATION, ALONG WITH THE REQUIRED FEE PURSUANT TO NAC 439.210, TO:

Richard Whitley, MS, Administrator
Nevada State Health Division
4150 Technology Way, Suite 300
Carson City, NV 89706

(See the attached table to determine the appropriate fee)



BASIS OF BEARING
GRAPHIC SCALE
N
CARSON CITY PARKS DEPARTMENT
CARSON CITY AIRPORT AUTHORITY
ADJUSTED PARCEL A
ADJUSTED PARCEL 8A
OLD BOUNDARY LINES
NEW BOUNDARY LINES
OLD HOT SPRINGS ROAD
RESEARCH WAY
HOLLY WAY
MARK WAY
STATE OF NEVADA
LLA-18-047
RECORD OF SURVEY
IN SUPPORT OF
A BOUNDARY LINE ADJUSTMENT
WESTERN INSURANCE COMPANY AND CARSON CITY HOLDING, LLC
LUMOS
SHEET 2 OF 2

EXHIBIT ___
LEGAL DESCRIPTION
OF ADJUSTED PARCEL 2A

A parcel of land in the East half of, Section 5 and the West half of Section 4, Township 15 North, Range 20 East, M.D.B. & M., Carson City, Nevada, more particularly described as follows:

Parcel 2 of a Parcel map for Richard K. Langson, Recorded January 29, 1996 under File No. 184746.

INCLUDING THERETO a parcel of land taken from the Southeast Quarter of the Northeast Quarter of Section 5 as shown on a Record of Survey in support of a Boundary line Adjustment for Richard K. Langson and Don K. and Toni K. Langson, Recorded February 18, 1999 under File No. 230483, more particularly described as follows;

BEGINNING at the Northeast corner of Parcel 2 of a Parcel map for Richard K. Langson, Recorded January 29, 1996 under File No. 184746;
THENCE North 00°10'42" East, 140.01 feet;
THENCE North 79°28'14" East, 337.45 feet;
THENCE South 01°45'45" East, 62.43 feet to the north line of Parcel 1 of Parcel Map for D.R.L. Investments, Recorded December 28, 1982 under File No. 15406;
THENCE along the north line of Parcel 1, North 89°52'33" West, 323.69 feet to a corner of Parcel 1;
THENCE continuing along a west line of Parcel 1, South 00°10'42" West, 140.00 feet to the south line of Southeast Quarter of the Northeast Quarter of Section 5;
THENCE along said south line, North 89°52'33" West, 10.00 feet to the **POINT OF BEGINNING.**

The above described area contains 11,812 square feet, more or less.

The basis of bearings for this description is the above described Record of Survey File No. 230483.

FURTHER INCLUDING THERETO a parcel of land taken from Parcel 1 of a Parcel map for Richard K. Langson, Recorded January 29, 1996 under File No. 184746 in the East half of Section 5 and the West half of Section 4 Township 15 North, Range 20 East, M.D.B. & M., Carson City, Nevada, more particularly described as follows;

BEGINNING at the Northwest corner of Parcel 1 of said Parcel Map for Richard K. Langson;
THENCE along the north line of Parcel 1, South 89°52'33" East, 323.69 feet;
THENCE South 01°45'45" East, 19.01 feet;
THENCE North 88°15'50" East, 17.99 feet;

THENCE on a curve concave to the southwest having a radial bearing of South 01°44'10" East a radius of 58.00 feet, a central angle of 57°45'06" and an arc length of 58.46 feet;
THENCE South 33°59'04" East, 17.95 feet;
THENCE South 06°12'18" East, 58.50 feet;
THENCE South 01°34'33" West, 108.22 feet;
THENCE South 08°21'57" West, 136.40 feet to a point on the northerly right of way of Old Hot Springs Road;
THENCE along said right of way, South 84°30'07" West, 398.72 feet to the Southwest corner of Parcel 1;
THENCE along the west line of Parcel 1, North 00°10'42" East, 259.09 feet;
THENCE South 89°52'33" East, 10.00 feet to a corner of Parcel 1;
THENCE North 00°10'42" East, 140.00 feet to the **POINT OF BEGINNING**.

The above described area contains 3.50 acres, more or less.

The basis of bearings for this survey is a Record of Survey in support of a Boundary line Adjustment for Richard K. Langson and Don K. and Toni K. Langson, Recorded February 18, 1999 under File No. 230483

FURTHER INCLUDING THERETO a parcel of land taken from the Southeast Quarter of the Northeast Quarter of Section 5 as shown on a Record of Survey in support of a Boundary line Adjustment for Western Insurance Company and Carson City Holdings, LLC, more particularly described as follows;

BEGINNING at a point on the south line of the Southeast Quarter of the Northeast Quarter of said Section 5, monumented with a 5/8" rebar with a 1.5" aluminum cap stamped PLS 9392, whence the East Center Sixteenth corner of Section 5 bears, North 89°08'06" West, 688.50 feet distant;
THENCE North 23°13'51" East, 70.80 feet to a point monumented with a 5/8" rebar with a 1.5" aluminum cap stamped PLS 9392;
THENCE South 89°03'57" East, 233.48 feet to a point, monumented with a 5/8" rebar with a 1.5" aluminum cap stamped PLS 9392, on the west line of Revised Parcel 2 as shown on a Record of Survey in support of a Boundary line Adjustment for Richard K. Langson and Don K. and Toni K. Langson, Recorded February 18, 1999 under File No. 230483;
THENCE along said west line, South 00°55'00" West, 65.19 feet to a point, monumented with a 5/8" rebar with a 1" plastic cap stamped PLS 5286, on the south line of the Southeast Quarter of the Northeast Quarter of said Section 5;
THENCE along said south line, North 89°08'06" West, 260.36 feet to the **POINT OF BEGINNING.**

The above described area contains 16,133 square feet, more or less.

The basis of bearings for this survey is NAD83, Nevada Coordinate System of 1983/94, West Zone, modified to ground using the combined scale factor of 1.0002. Referenced to the Carson City Control Network of 2010

EXCEPTING THEREFROM a parcel of land taken from the Northeast Quarter of the Southeast Quarter of Section 5 and a portion of Revised Parcel 2 of a Record of Survey in support of a Boundary line Adjustment for Richard K. Langson and Don K. and Toni K. Langson, Recorded February 18, 1999 under File No. 230483, as shown on a Record of Survey in support of a Boundary line Adjustment for Western Insurance Company and Carson City Holdings, LLC, more particularly described as follows;

BEGINNING at a point on the south line of the Southeast Quarter of the Northeast Quarter of said Section 5, monumented with a 5/8" rebar with a 1" plastic cap stamped PLS 6304, whence the East Center Sixteenth corner of Section 5 bears, North 89°08'06" West, 603.61 feet distant;
THENCE along the south line of the Southeast Quarter of the Northeast Quarter of said Section 5, South 89°08'06" East, 84.89 feet to a point monumented with a 5/8" rebar with a 1.5" aluminum cap stamped PLS 9392;
THENCE South 23°13'51" West, 91.89 feet to a point monumented with a 5/8" rebar with a 1.5" aluminum cap stamped PLS 9392;
THENCE South 00°55'00" West, 110.38 feet to a point monumented with a 5/8" rebar with a 1.5" aluminum cap stamped PLS 9392;
THENCE South 15°32'10" East, 94.19 feet to a point on the North line of Old Hot Springs Road monumented with a 5/8" rebar with a 1.5" aluminum cap stamped PLS 9392;
THENCE along the north line of Old Hot Springs Road on a curve concave to the southeast, having a radial bearing of South 06°11'08" East a radius of 1130.56 feet, an arc length of 50.50 feet and a delta of 02°33'34" to the Southwest corner of the above said Revised Parcel 2;
THENCE along the west line of said Revised Parcel 2, North 15°32'10" West, 94.33 feet;
THENCE continuing along said West line, North 00°55'00" East, 202.54 feet to the **POINT OF BEGINNING.**

The above described area contains 16,133 square feet, more or less.

The basis of bearings for this survey is NAD83, Nevada Coordinate System of 1983/94, West Zone, modified to ground using the combined scale factor of 1.0002. Referenced to the Carson City Control Network of 2010

Prepared by: Dean Neubauer, P.L.S. 9392, 800 E. College Parkway, Carson City, NV, 89706

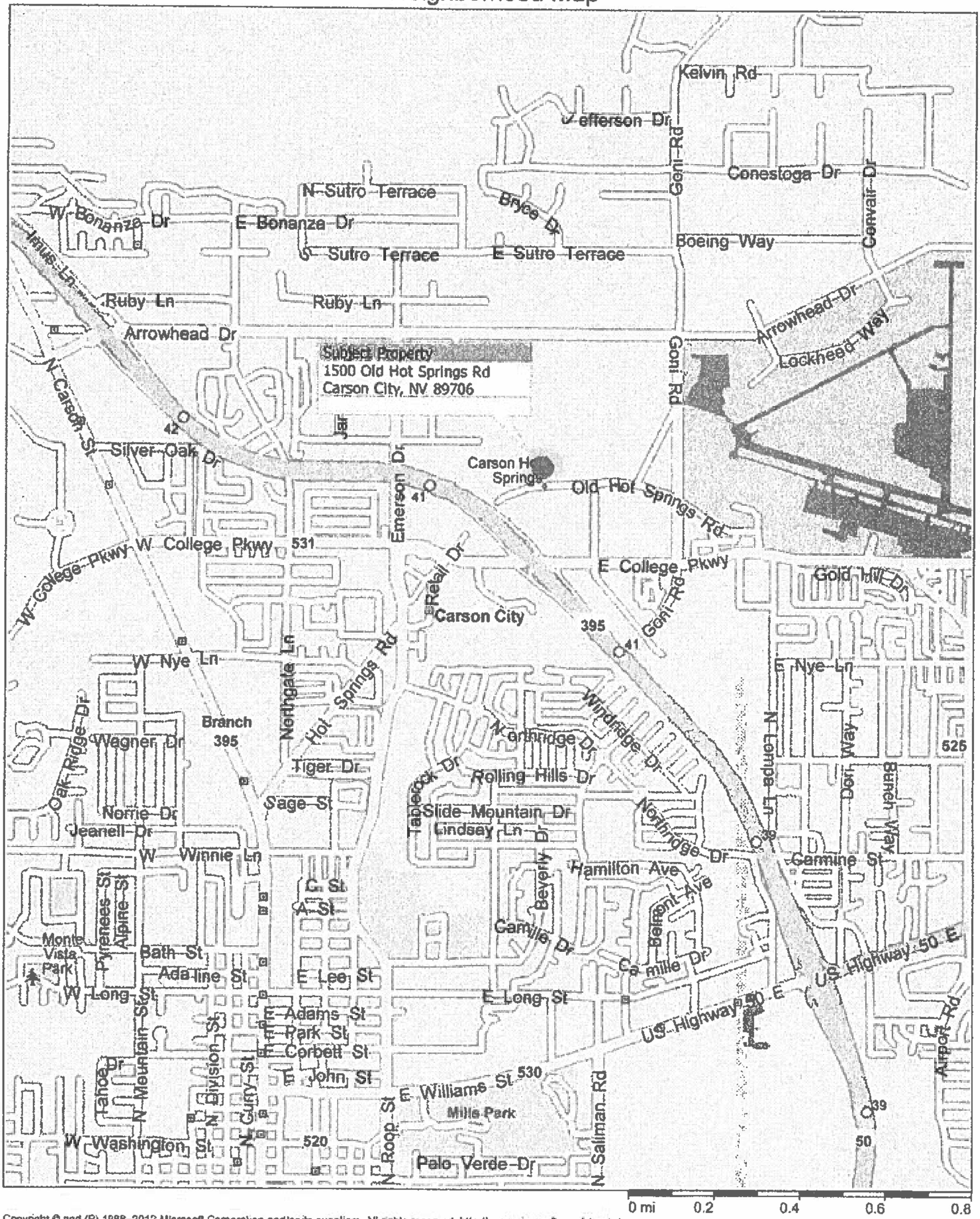
PROFESSIONAL LAND SURVEYOR STATE OF NEVADA
DEAN NEUBAUER
Exp 12/31/17
No. 9392

5/31/16

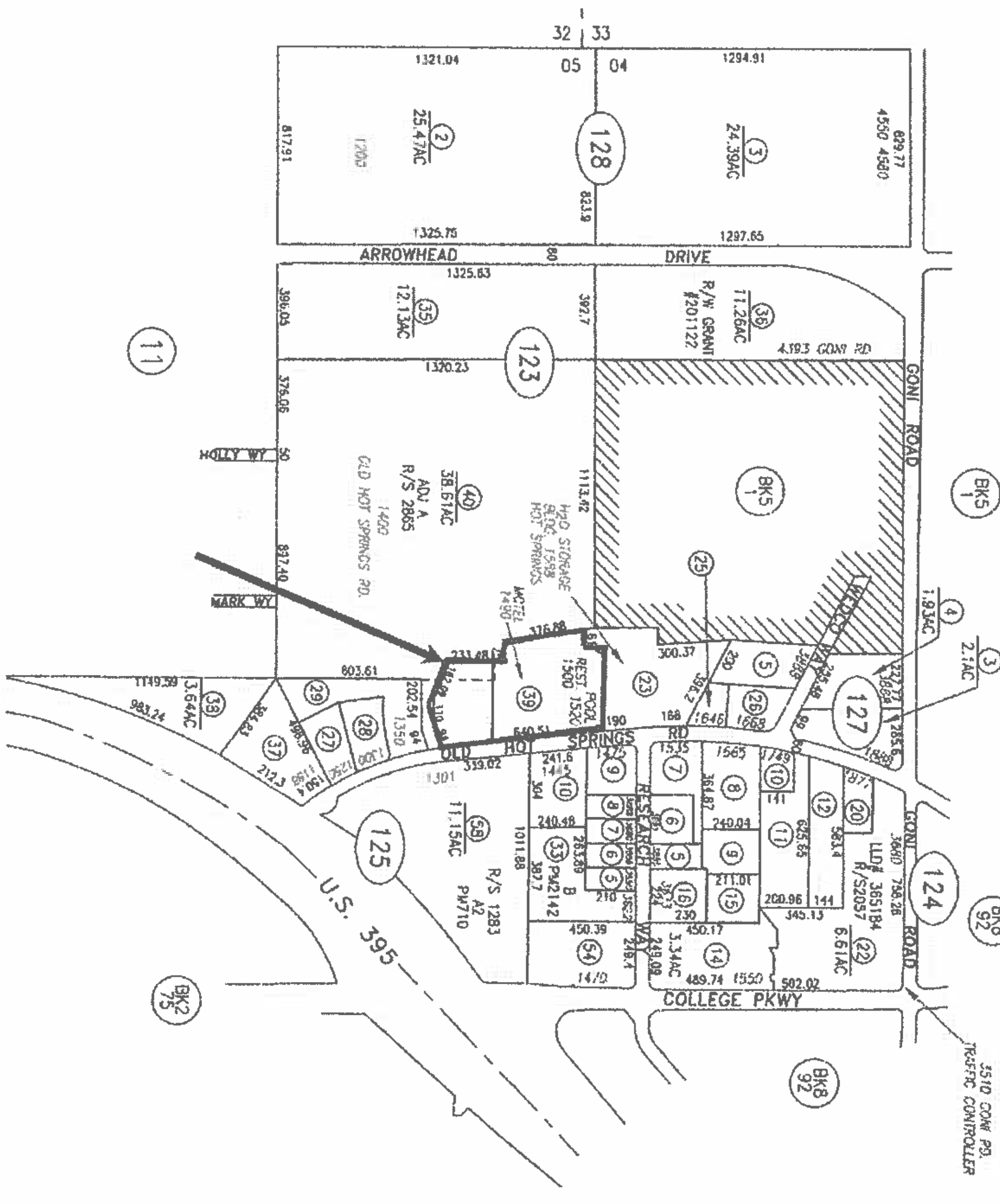
As a reference only and not to be used to transfer land title the following is a brief meets and bounds description of the exterior boundary of the above described parcel as required by the Carson City Planning Department:

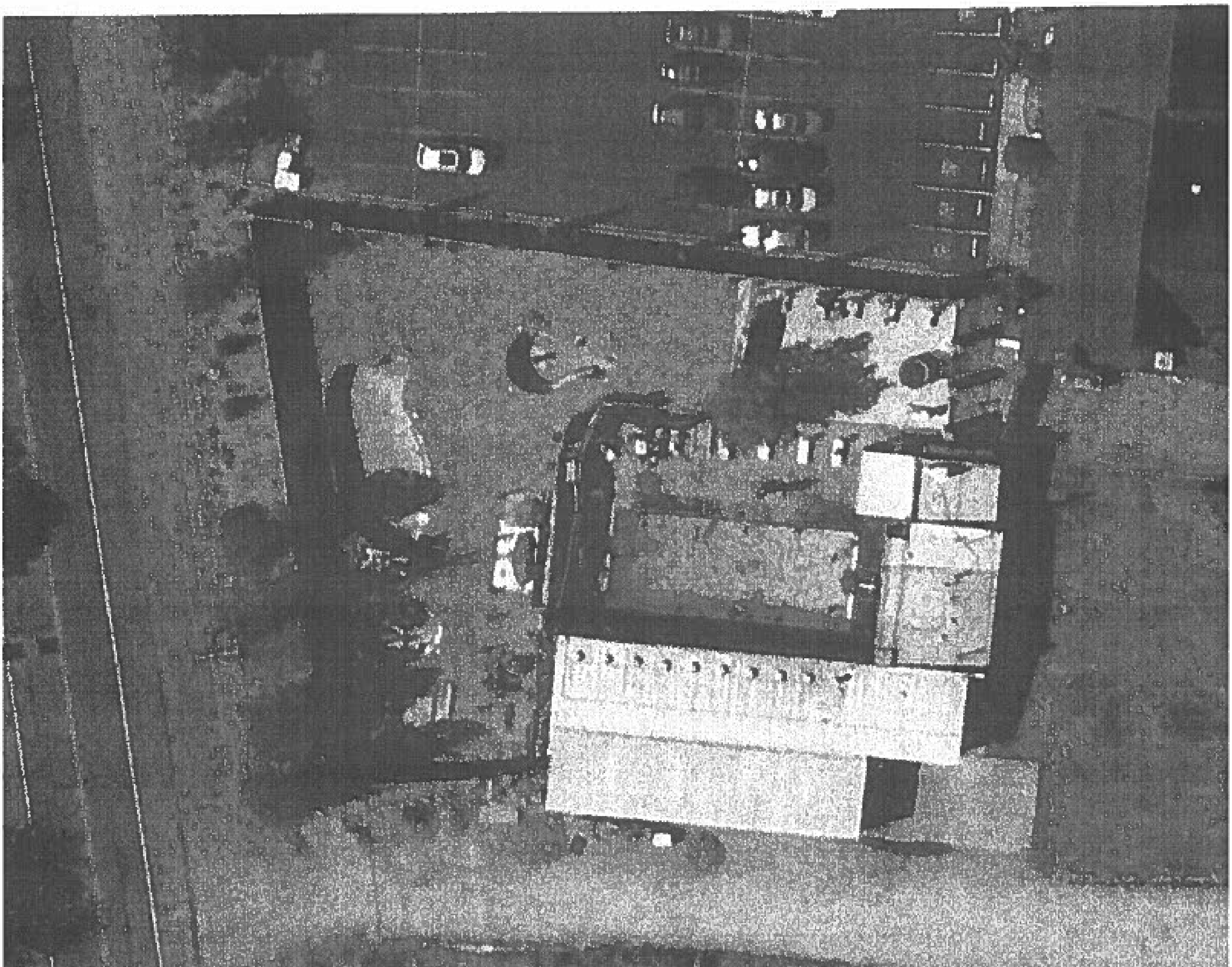
BEGINNING at a point on the south line of the Southeast Quarter of the Northeast Quarter of said Section 5 whence the East Center Sixteenth corner of Section 5 bears, North 89°08'06" West, 688.50 feet distant;
THENCE North 23°13'51" East, 70.80 feet;
THENCE South 89°03'57" East, 233.48 feet;
THENCE North 00°55'00" East, 75.01 feet;
THENCE North 80°12'32" East, 337.45 feet;
THENCE South 01°01'27" East, 81.43 feet;
THENCE North 89°00'08" East, 17.99 feet;
THENCE on a curve concave to the southwest having a radius of 58.00 feet, a central angle of 57°45'01" and an arc length of 58.46 feet;
THENCE South 33°14'46" East, 17.95 feet;
THENCE South 05°28'00" East, 58.50 feet;
THENCE South 02°18'51" West, 108.22 feet;
THENCE South 09°06'15" West, 136.40 feet;
THENCE South 85°14'25" West, 640.51 feet;
THENCE on a curve concave to the southeast, having a radius of 1130.56 feet, an arc length of 50.50 feet and a delta of 02°33'34";
THENCE North 15°32'10" West, 94.19 feet;
THENCE North 00°55'00" East, 110.38 feet
THENCE North 23°13'51" East, 91.89 feet to the **POINT OF BEGINNING.**
Containing 5.94 acres, more or less.

Neighborhood Map



ASSESSOR'S PLAT MAP
(Entire Parcel – 008-123-39)





Carson City Property Inquiry

Property Information

Parcel ID	008-123-39	**Parcel Acreage**	5.9400
Tax Year	2021	**Assessed Value**	618,340
Land Use Group	COM	**Tax Rate**	3.5700
Land Use	490 - Mixed Use with Commercial as Primary Use	**Total Tax Fiscal Year (2021 - 2022)**	$20,660.40
Zoning	TC	**Total Unpaid All Years**	$20,660.40
Tax District	024		Pay Taxes
Site Address	1500 OLD HOT SPRINGS RD 1520 OLD HOT SPRINGS RD POOL 1490 OLD HOT SPRINGS RD MOTEL 1496 OLD HOT SPRINGS RD 1510 OLD HOT SPRINGS RD		

Public Notes

FIREPLACE, 30% SLAB FLOOR, LIVING ROOM, DINING AREA, 3 BEDROOMS, 1 BATH

(20/21) 2 NEW POOLS, (21/22) NEW POOL, NEW PARKING LOT AND WATER FEATURE

SHOWER BLDG: AVERAGE STORY HEIGHT: 12 FT 2 & 1/2 BATHS

RESTAURANT BLDG:AVERAGE STORY HEIGHT: 10 FT, PORCH

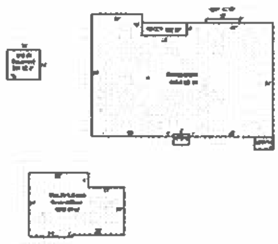
LAUNDROMAT BLDG: AVERAGE STORY HEIGHT: 8 FT

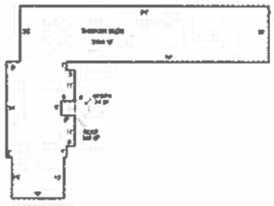
MOTEL BLDG 3A, 3B, 3C: AVERAGE STORY HEIGHT: 8 FT, ROOFED PORCH

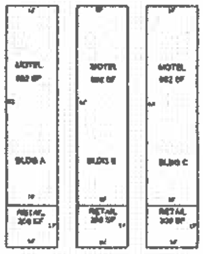
WAREHOUSE: AVERAGE STORY HEIGHT: 10FT

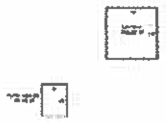
BREWERY: BAR, CUSTOMER SEATING AREA, MEN & WOMENS BATHROOM, BREWERY TANKS, WALKIN COOLER, 100% COMPLETE FOR 17/18

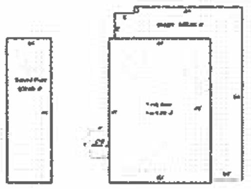
Sketches & Photos

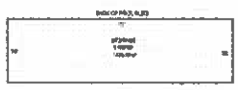


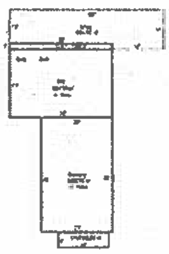




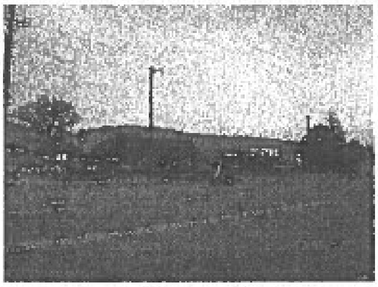




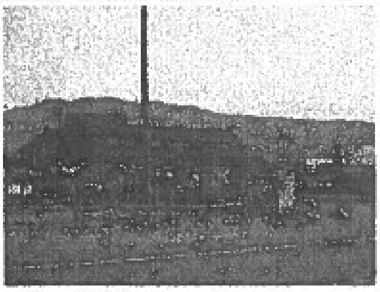




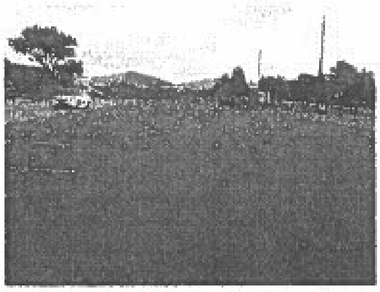
Imported Image



Imported Image



Imported Image



Gmail Mark Begich <markbegich@gmail.com>

Fwd: 210885-47820 E-BILL
1 message

KS Email <keithnev52@gmail.com> Mon, Feb 1, 2021 at 6:03 PM
To: Mark Begich <markbegich@gmail.com>

---------- Forwarded message ---------
From: <UTILITYBILLING@carson.org>
Date: Mon, Feb 1, 2021 at 6:36 PM
Subject: 210885-47820 E-BILL
To: <keithnev52@gmail.com>

Electronic Notification Information

You have a new e-notification from: CARSON CITY UTILITIES
Account number : 210885-47820 Cycle/Route: 13-64
Location Address: 1500 OLD HOT SPRINGS RD
CARSON CITY NV 89706
Customer Name : CARSON CITY HOLDING LLC
Mailing Address : 1500 OLD HOT SPRINGS RD
City/State/Zip : CARSON CITY NV 89706-0602
Bill Date : 1/30/21 Auto pay date: 2/12/21
Bill Period : 01/ 21

*** Auto Pay (CREDIT CARD) do not pay ***
Balance forward : $0.00
Payments / adj. : $0.00
Current charges : $7,569.59
Bill amount : $7,569.59

Reading information

Service	Read date	Type	Meter_number	Days	Actual Consumption	Demand Consumption
W	1/26/21	Regular	00034048599	33	473.00	.00

Current Charge Detail

Code	Description	Amount
S	SEWER	5,706.99
SD	STORM WATER PROGRAM	40.96
W	WATER	1,747.10
	TAXES	74.54
	Total Actual Charges	7,569.59

Balance : $7,569.59 as of 2/01/21

To view this bill please select or copy and paste the URL below into your Web browser address field:

https://payments.carson.org/Click2GovCX/index.html
Reply to address: UTILITYBILLING@CARSON.ORG

Gmail Mark Begich <markbegich@gmail.com>

Fwd: 210885-47820 E-BILL
1 message

KS Email <keithnev52@gmail.com> Tue, Aug 3, 2021 at 8:58 AM
To: Mark Begich <markbegich@gmail.com>

---------- Forwarded message ---------
From: <UTILITYBILLING@carson.org>
Date: Mon, Jan 4, 2021 at 7:36 PM
Subject: 210885-47820 E-BILL
To: <keithnev52@gmail.com>

Electronic Notification Information

You have a new e-notification from: CARSON CITY UTILITIES
Account number : 210885-47820 Cycle/Route: 13-64
Location Address: 1500 OLD HOT SPRINGS RD
CARSON CITY NV 89706
Customer Name : CARSON CITY HOLDING LLC
Mailing Address : 1500 OLD HOT SPRINGS RD
City/State/Zip : CARSON CITY NV 89706-0602
Bill Date : 1/01/21 Auto pay date: 1/14/21
Bill Period : 12/ 20

*** Auto Pay (CREDIT CARD) do not pay ***
Balance forward : $0.00
Payments / adj. : $0.00
Current charges : $1,413.21
Bill amount : $1,413.21

Reading information

Service	Read date	Type	Meter_number	Days	Actual	Demand	Consumption
W	12/24/20	Regular	00034048599	30	80.00	.00	

Current Charge Detail

Code	Description	Amount
S	SEWER	998.85
SD	STORM WATER PROGRAM	40.96
W	WATER	359.81
	TAXES	13.59
	Total Actual Charges	1,413.21

Balance : $1,413.21 as of 1/04/21

To view this bill please select or copy and paste the URL below into your Web browser address field:

https://payments.carson.org/Click2GovCX/index.html
Reply to address: UTILITYBILLING@CARSON.ORG

Gmail

Mark Begich <markbegich@gmail.com>

Fwd: 210885-47820 E-BILL
1 message

KS Email <keithnev52@gmail.com> Tue, Aug 3, 2021 at 8:59 AM
To: Mark Begich <markbegich@gmail.com>

---------- Forwarded message ---------
From: <UTILITYBILLING@carson.org>
Date: Wed, Dec 2, 2020 at 6:50 PM
Subject: 210885-47820 E-BILL
To: <keithnev52@gmail.com>

Electronic Notification Information

You have a new e-notification from: CARSON CITY UTILITIES
Account number : 210885-47820 Cycle/Route: 13-64
Location Address: 1500 OLD HOT SPRINGS RD
CARSON CITY NV 89706
Customer Name : CARSON CITY HOLDING LLC
Mailing Address : 1500 OLD HOT SPRINGS RD
City/State/Zip : CARSON CITY NV 89706-0602
Bill Date : 12/02/20 Auto pay date: 12/15/20
Bill Period : 11/ 20

*** Auto Pay (CREDIT CARD) do not pay ***
Balance forward : $0.00
Payments / adj. : $0.00
Current charges : $1,851.83
Bill amount : $1,851.83

Reading information

Service	Read date	Type	Meter_number	Days	Actual Consumption	Demand Consumption
W	11/24/20	Regular	00034048599	33	108.00	.00

Current Charge Detail

Code	Description	Amount
S	SEWER	1,334.29
SD	STORM WATER PROGRAM	40.96
W	WATER	458.65
	TAXES	17.93
	Total Actual Charges	1,851.83

Balance : $1,851.83 as of 12/02/20

To view this bill please select or copy and paste the URL below into your Web browser address field:

https://payments.carson.org/Click2GovCX/index.html
Reply to address: UTILITYBILLING@CARSON.ORG

Nevada State Public Health Laboratory

University of Nevada, Reno
1660 North Virginia Street
Reno, Nevada 89503-0703
(775) 688-1335 / (775) 688-1460 Fax

Director: Marcus Erling, MD
CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID: NV0002000

Accession Number:	EN2021-00013860	
Date/Time Collected	07/01/2021	07:00
Date/Time Received:	07/01/2021	09:52
Date/Time Reported:	07/02/2021	10:40

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				07/01/2021	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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Nevada State Public Health Laboratory

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CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

CC HOLDING LLC
1500 OLD HOT SPRINGS RD
CARSON CITY, NV 89706

PWS # or Client ID: NV0002000

Accession Number:	EN2021-00013371	
Date/Time Collected	06/01/2021	07:00
Date/Time Received:	06/01/2021	09:08
Date/Time Reported:	06/02/2021	11:24

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				06/01/2021	KYWANG

Report Reviewed by: Kaelien Wang
Analyst

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CAP: 2248701
NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID: NV0002000

Accession Number:	**EN2021-00012997**	
Date/Time Collected	05/03/2021	07:00
Date/Time Received:	05/03/2021	09:35
Date/Time Reported:	05/04/2021	10:57

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	For Compliance

Sample Type: Routine
Sampling Location: POOL
Sample Collection Point: 1500 OLD HOT SPRINGS RD
Collected By: KEITH SHELLHAMMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				05/03/2021	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID: NV0002000

Accession Number:	EN2021-00012683	
Date/Time Collected	04/01/2021	07:00
Date/Time Received:	04/01/2021	08:13
Date/Time Reported:	04/02/2021	10:55

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				04/01/2021	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID: NV0002000

Accession Number: EN2021-00012291

Date/Time Collected	03/02/2021	07:30
Date/Time Received:	03/02/2021	08:28
Date/Time Reported:	03/03/2021	11:35

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				03/02/2021	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

Nevada State Public Health Laboratory

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CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

Carson City Holding, LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID:

Accession Number:	EN2018-00000936	
Date/Time Collected	02/14/2018	06:00
Date/Time Received:	02/15/2018	10:32
Date/Time Reported:	02/16/2018	9:02

Analysis Type: Liquid	Carson
Program Type	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				02/15/2018	JCONDON

Report Reviewed by: Juliet Condon
Analyst

Nevada State Public Health Laboratory
University of Nevada, Reno
1660 North Virginia Street
Reno, Nevada 89503-0703
(775) 688-1335 / (775) 688-1460 Fax

Director: Marcus Erling, MD
CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID: NV0002000

Accession Number:	EN2021-00011967	
Date/Time Collected	02/01/2021	06:00
Date/Time Received:	02/01/2021	09:23
Date/Time Reported:	02/02/2021	10:38

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not Indicated

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA ualitative	9223B-PA	Absent				02/01/2021	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID: NV0002000

Accession Number:	EN2021-00011659	
Date/Time Collected	01/04/2021	05:30
Date/Time Received:	01/04/2021	08:37
Date/Time Reported:	01/05/2021	10:56

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				01/04/2021	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

Nevada State Public Health Laboratory

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1660 North Virginia Street
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CAP: 2248701
NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID: NV0002000

Accession Number:	**EN2020-00011251**	
Date/Time Collected	12/01/2020	06:00
Date/Time Received:	12/01/2020	08:48
Date/Time Reported:	12/02/2020	12:22

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				12/01/2020	JCONDON

Report Reviewed by: Juliet Condon
Analyst

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Director: Marcus Erling, MD
CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID: NV0002000

Accession Number:	EN2020-00010876	
Date/Time Collected	11/02/2020	06:00
Date/Time Received:	11/02/2020	08:24
Date/Time Reported:	11/03/2020	10:41

Analysis Type: Liquid Carson
Program Type: SDWA
Attestation Received? Yes
Chlorine Residual:
Compliance Sample? Not Indicated

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

est Name	Method	Result	Units	RL	MCL	Date of Analysis	
efault							
otal Coliform SDWA alitative	9223B-PA	Absent				11/02/2020	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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(775) 688-1335 / (775) 688-1460 Fax

Director: Marcus Erling, MD
CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

CC HOLDING LLC
1500 OLD HOT SPRINGS RD
CARSON CITY, NV 89706

PWS # or Client ID:

Accession Number:	EN2020-00010719	
Date/Time Collected	10/19/2020	06:00
Date/Time Received:	10/19/2020	08:35
Date/Time Reported:	10/20/2020	12:27

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				10/19/2020	JCONDON

Report Reviewed by: Juliet Condon
Analyst

University of Nevada, Reno
1660 North Virginia Street
Reno, Nevada 89503-0703
(775) 688-1335 / (775) 688-1460 Fax

Director: Marcus Erling, MD
CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID: NV0002000

Accession Number:	**EN2020-00009036**	
Date/Time Collected	07/01/2020	07:00
Date/Time Received:	07/01/2020	10:25
Date/Time Reported:	07/02/2020	10:57

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

est Name	Method	Result	Units	RL	MCL	Date of Analysis	
efault							
·tal Coliform SDWA alitative	9223B-PA	Absent				07/01/2020	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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Nevada State Public Health Laboratory

University of Nevada, Reno
1660 North Virginia Street
Reno, Nevada 89503-0703
(775) 688-1335 / (775) 688-1460 Fax

Director: Marcus Erling, MD
CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

CC HOLDING LLC
1500 OLD HOT SPRINGS RD
CARSON CITY, NV 89706

PWS # or Client ID: NV0002000

Accession Number:	**EN2020-00008636**	
Date/Time Collected	06/02/2020	05:30
Date/Time Received:	06/02/2020	07:13
Date/Time Reported:	06/03/2020	11:22

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				06/02/2020	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID:

Accession Number:	EN2020-00007513	
Date/Time Collected	03/02/2020	06:50
Date/Time Received:	03/02/2020	09:59
Date/Time Reported:	03/03/2020	11:04

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				03/02/2020	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID:

Accession Number:	EN2020-00007017	
Date/Time Collected	02/03/2020	07:00
Date/Time Received:	02/03/2020	09:55
Date/Time Reported:	02/04/2020	11:02

Analysis Type: Liquid Carson
Program Type: SDWA
Attestation Received? Yes
Chlorine Residual:
Compliance Sample? Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRING RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				02/03/2020	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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Director: Marcus Erling, MD
CLIA: 29D06527-48
CAP: 2248701
NV State: 1479PHL-0

Carson City Holding LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID:

Accession Number:	EN2020-00006601
Date/Time Collected	01/06/2020 07:00
Date/Time Received:	01/06/2020 09:54
Date/Time Reported:	01/07/2020 11:50

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				01/06/2020	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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PWS # or Client ID:

Accession Number:	EN2019-00006066	
Date/Time Collected	12/02/2019	08:00
Date/Time Received:	12/02/2019	11:44
Date/Time Reported:	12/03/2019	11:03

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				12/02/2019	KYWANG

Report Reviewed by: Kaellen Wang
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PWS # or Client ID:

Accession Number:	**EN2019-00005681**	
Date/Time Collected	11/12/2019	09:00
Date/Time Received:	11/12/2019	11:04
Date/Time Reported:	11/13/2019	11:01

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				11/12/2019	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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PWS # or Client ID:

Accession Number:	**EN2019-00004953**		
Date/Time Collected		10/01/2019	07:00
Date/Time Received:		10/01/2019	11:30
Date/Time Reported:		10/02/2019	11:00

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				10/01/2019	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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PWS # or Client ID: NV0002000

Accession Number:	EN2019-00004313	
Date/Time Collected	09/04/2019	07:00
Date/Time Received:	09/04/2019	09:31
Date/Time Reported:	09/05/2019	12:20

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				09/04/2019	JCONDON

Report Reviewed by: Juliet Condon
Analyst

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PWS # or Client ID: NV0002000

Accession Number:	**EN2019-00003953**	
Date/Time Collected	08/13/2019	07:00
Date/Time Received:	08/13/2019	08:45
Date/Time Reported:	08/14/2019	12:00

Analysis Type: Liquid Carson
Program Type: SDWA
Attestation Received? Yes
Chlorine Residual:
Compliance Sample? Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT WATER SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				08/13/2019	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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PWS # or Client ID: NV0002000

Accession Number:	**EN2019-00003082**	
Date/Time Collected	07/01/2019	08:00
Date/Time Received:	07/02/2019	10:32
Date/Time Reported:	07/03/2019	12:04

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1800 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				07/02/2019	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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PWS # or Client ID: NV0002000

Accession Number:	EN2019-00002471	
Date/Time Collected	06/03/2019	08:30
Date/Time Received:	06/04/2019	10:50
Date/Time Reported:	06/05/2019	12:11

Analysis Type: Liquid Carson
Program Type: SDWA
Attestation Received? Yes
Chlorine Residual:
Compliance Sample? Not Indicated

Sample Type:
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				06/04/2019	KYWANG

Report Reviewed by: Kaellen Wang
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PWS # or Client ID:

Accession Number:	**EN2019-00001935**	
Date/Time Collected	05/08/2019	08:20
Date/Time Received:	05/09/2019	10:26
Date/Time Reported:	05/10/2019	12:09

Analysis Type: Liquid Carson
Program Type: SDWA
Attestation Received? Yes
Chlorine Residual:
Compliance Sample? Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRING RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				05/09/2019	JCONDON

Report Reviewed by: Juliet Condon
Analyst

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PWS # or Client ID:

Accession Number:	EN2019-00001371	
Date/Time Collected	04/08/2019	08:00
Date/Time Received:	04/08/2019	08:43
Date/Time Reported:	04/09/2019	11:29

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				04/08/2019	KPARRISHMULLI

Report Reviewed by: Kaitlin Parrish Mullin
Data Entry

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PWS # or Client ID:

Accession Number:	**EN2019-00000942**
Date/Time Collected	03/12/2019 07:00
Date/Time Received:	03/12/2019 09:09
Date/Time Reported:	03/13/2019 13:23

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRING RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				03/12/2019	KYWANG

Report Reviewed by: Kaellen Wang
Analyst

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PWS # or Client ID:

Accession Number:	**EN2019-00000435**	
Date/Time Collected	02/05/2019	07:00
Date/Time Received:	02/05/2019	08:39
Date/Time Reported:	02/06/2019	9:52

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				02/05/2019	JCONDON

Report Reviewed by: Juliet Condon
Analyst

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PWS # or Client ID:

Accession Number:	**EN2019-00000120**	
Date/Time Collected	01/07/2019	06:00
Date/Time Received:	01/09/2019	10:35
Date/Time Reported:	01/09/2019	10:44

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Cancelled Test	Default	Total Coliform - SDWA				01/09/2019	SGIRON

Notification: Called To: Nielsa S.
Date: 01/09/2019 Time: 10:30
Called By: sg
Cancel Reason: Received Sample out of hold time.

Report Reviewed by: Sandy Giron
Data Entry

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PWS # or Client ID:

Accession Number:	**EN2018-00006062**	
Date/Time Collected	12/04/2018	07:10
Date/Time Received:	12/05/2018	10:58
Date/Time Reported:	12/06/2018	14:25

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRING RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				12/05/2018	LMUIR

Report Reviewed by: LORRIE MUIR
Analyst

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PWS # or Client ID:

Accession Number:	EN2018-00005737		
Date/Time Collected	11/07/2018	07:00	
Date/Time Received:	11/08/2018	10:27	
Date/Time Reported:	11/09/2018	9:09	

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: POOL 1500 OLD HOT SPRINGS
Sample Collection Point: POLL CARSON CITY NV 89706
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				11/08/2018	KPARRISHMULLI

Report Reviewed by: Kaitlin Parrish Mullin
Data Entry

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PWS # or Client ID:

Accession Number:	EN2018-00005258	
Date/Time Collected	10/09/2018	09:00
Date/Time Received:	10/10/2018	10:23
Date/Time Reported:	10/11/2018	11:52

Analysis Type: Liquid Carson
Program Type: SDWA
Attestation Received? Yes
Chlorine Residual:
Compliance Sample? Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				10/10/2018	JCONDON

Report Reviewed by: Juliet Condon
Analyst

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PWS # or Client ID:

Accession Number:	**EN2018-00004634**
Date/Time Collected	09/10/2018 08:30
Date/Time Received:	09/11/2018 11:00
Date/Time Reported:	09/12/2018 11:28

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				09/11/2018	JCONDON

Report Reviewed by: Juliet Condon
Analyst

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PWS # or Client ID:

Accession Number:	EN2018-00003793	
Date/Time Collected	08/01/2018	10:00
Date/Time Received:	08/02/2018	11:40
Date/Time Reported:	08/03/2018	11:23

Analysis Type: Liquid — Carson
Program Type: SDWA
Attestation Received? Yes
Chlorine Residual:
Compliance Sample? Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				08/02/2018	BECKLEY

Report Reviewed by: Brandy Eckley
Data Entry

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PWS # or Client ID:

Accession Number:	EN2018-00003339	
Date/Time Collected	07/02/2018	05:00
Date/Time Received:	07/03/2018	11:21
Date/Time Reported:	07/05/2018	12:53

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Comments:

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				07/05/2018	BECKLEY

ANALYZED OUT OF HOLD TIME

Report Reviewed by: Brandy Eckley
Data Entry

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PWS # or Client ID:

Accession Number:	**EN2018-00002759**	
Date/Time Collected	06/05/2018	06:00
Date/Time Received:	06/06/2018	11:12
Date/Time Reported:	06/07/2018	9:51

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				06/06/2018	JCONDON

Report Reviewed by: Juliet Condon
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Director: Marcus Erling, MD
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CAP: 2248701
NV State: 1479PHL-0

Carson City Holding, LLC
Attn:
Keith Shellhamer
1500 Hot Springs Road
Carson City, NV 89706

PWS # or Client ID:

Accession Number:	**EN2018-00002273**	
Date/Time Collected	05/09/2018	05:30
Date/Time Received:	05/10/2018	11:18
Date/Time Reported:	05/11/2018	12:22

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				05/10/2018	JCONDON

Report Reviewed by: Juliet Condon
Analyst

Note: This document will be destroyed at NSPHL after 12 years unless Client requests otherwise.

Nevada State Public Health Laboratory
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PWS # or Client ID:

Accession Number:	EN2018-00001670	
Date/Time Collected	04/04/2018	06:00
Date/Time Received:	04/05/2018	11:17
Date/Time Reported:	04/06/2018	12:40

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered on ice

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				04/05/2018	JCONDON

Report Reviewed by: Juliet Condon
Analyst

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PWS # or Client ID: NV0002000

Accession Number:	EN2018-00001125	
Date/Time Collected	03/05/2018	05:00
Date/Time Received:	03/06/2018	10:45
Date/Time Reported:	03/07/2018	11:20

Analysis Type: Liquid	Carson
Program Type:	SDWA
Attestation Received?	Yes
Chlorine Residual:	
Compliance Sample?	Not For Compliance

Sample Type: Routine
Sampling Location: 1500 OLD HOT SPRINGS RD
Sample Collection Point: POOL
Collected By: KEITH SHELLHAMER
Temperature at Receipt (C): delivered direct from site

Test Name	Method	Result	Units	RL	MCL	Date of Analysis	
Default							
Total Coliform SDWA Qualitative	9223B-PA	Absent				03/07/2018	JCONDON

Report Reviewed by: Juliet Condon
Analyst

Note: This document will be destroyed at NSPHL after 12 years unless Client requests otherwise.

BEFORE THE STATE BOARD OF HEALTH

IN THE MATTER OF)

MARK BEGICH WITH CARSON CITY HOLDING)

VARIANCE REQUEST: CASE #721)

The Nevada State Board of Health ("Board"), having considered the application for a variance and all other related documents submitted in support of the application in the above referenced matter, makes the following Findings of Fact, Conclusions of Law, and Decision.

FINDINGS OF FACT

1. On August 1, 2021, the Division of Public & Behavioral Health ("Division") received a request for variance from NAC 444.178(1).
2. NAC 444.178(1) states: "A public bathing or swimming facility must be equipped with a chlorinator, hypochlorinator or other disinfectant feeder."
3. Mr. Begich is requesting that the variance provide on September 19, 2018 (#694) be modified to allow his flow through pools and spas to be increase from six hours to twelve hours, his preference is to not require a turnover rate for the Flow-Through Water Exchange system which was approved in 2018.
4. Variance #721 modifies variance #694 provided on September 19, 2018 to 1) Test water quality for public safety at least monthly or as often as required by the local regulatory authority, 2) increase the turnover rate to twelve hours for all public bathing pools and spas, 3) each pool and spa must be drained, cleaned and sanitized before use the next day.
5. Mr. Begich's property is located at the Historic Carson City Hot Springs in Carson City, Nevada. The property currently has two outdoor pools, nine mini spas/soaking rubs and two large jacuzzies. They are open from 7 AM to 10 PM daily, for a total of 15 hours. The

water enters the pool from one end and drained on the other end. The water flows through the pools spas and jacuzzies all day and then drained and sanitized at the end of the day. This system is used to keep the water clean and temperature controlled.

6. Based on the studies performed by Gage-Bidwell shows that it takes over 24 hours to completely ensure a complete exchange of water. The previous variance ensured that water would be turned over at least twice during the period of operation.

CONCLUSIONS OF LAW

1. This matter is properly before the board pursuant to NRS 439.200 and determination of the matter on the merits is properly within the subject matter jurisdiction of the board.

2. NRS 439.200 provides:

The State Board of Health may grant a variance from the requirements of a regulation if it finds that:

(a) Strict application of that regulation would result in exceptional and undue hardship to the person requesting the variance; and

(b) The variance, if granted would not:

(1) Cause substantial detriment to the public welfare; or

(2) Impair substantially the purpose of the regulation.

3. While the strict application of NAC 444.178(1) would require the Caron Hot Springs to increase costs and use equipment to add city water and maintain a six hour turnover provide by variance #694, the Board find that granting this variance would cause substantial determent to the public welfare and impair substantially the purpose of the regulation.

ORDER

Based upon the foregoing Findings of Fact and Conclusions of Law, and good cause appearing, therefore, IT IS HEREBY ORDERED, ADJUDGED, AND DECREED that the variance to NAC 444.8301(5) be DENIED.

DATED this________________day of_________________, 2021.

____
Lisa Sherych, Executive Officer
Nevada State Board of Health

CERTIFICATE OF MAILING

I hereby certify that I am employed by the Department of Health & Human Services, Division of Public & Behavioral Health, and that on the ___________day of___________, 2021, I served the foregoing FINDINGS OF FACTS AND DECISION by mailing a copy thereof to:

Mr. Mark Begich

Carson City Holding LLC

6447 Colgate Drive

Anchorage, AK 99504

____

Memo

Date: November 19, 2021

To: State of Nevada Board of Health

From: Dustin Boothe, REHS, MPH, Disease Prevention and Control Manager

RE: Carson City Hot Springs Variance Request #721 to modify variance #694

Carson City Health and Human Services (CCHHS), Disease Prevention and Control Division (DPC), Environmental Health Program (EH) does not support the variance request #721 the modification of variance #694.

Complete turnover of water in pools/spas is one of the public health standards that provides for the safe use of pools/spas to the public. By allowing the turnover rate to increase to 12 hours with no other public health measures (such as chemical disinfectant) in place, is potentially putting the users of these pools/spas at increased risk of waterborne illness.

Steve Sisolak
Governor

Richard Whitley, MS
Director

DEPARTMENT OF HEALTH AND HUMAN SERVICES

DIVISION OF PUBLIC AND BEHAVIORAL HEALTH

Helping people. It's who we are and what we do.

Lisa Sherych
Administrator

Ihsan Azzam, Ph.D., M.D.
Chief Medical Officer

MEMORANDUM

DATE: November 19, 2021

TO: Jon Pennell, DVM, Chairperson
State Board of Health

FROM: Lisa Sherych, Secretary
State Board of Health

RE: Case #721, Mr. Mark Begich with Carson City Holding (Carson Hot Springs)

Nevada Administrative Code (NAC) 444.178(1) states:

1. "A public bathing or swimming facility must be equipped with a chlorinator, hypochlorinator, or other disinfectant feeders."

STAFF REVIEW

Variance applicant Mark Begich ("Applicant") submitted a request for a variance from the requirements of NAC 444.178(1) on August 1, 2021. The Applicant is requesting approval to modify the variance provided on September 19, 2018, variance # 694, which allowed the facility to use a flow-through system instead of a chemical feeder system and disinfectants to maintain sanitary water conditions in the pools, spas, and Jacuzzi's. Chemical disinfection for public bathing facilities utilizes recirculated water and mechanical filtration system to prevent waterborne disease outbreaks associated with public aquatic facilities.

Mr. Begich's current request is to raise the turnover rate from six to twelve hours or eliminate turnover to better adjust for temperature fluctuations during the year. The temperatures are controlled by adding city water to the geothermal water to reduce the temperature. The addition of city water has increased the cost of maintaining temperature control in the pools. In addition, the cost of the equipment to ensure that this process is automated is expensive and hard to come by. In 2018, Carson Hot Springs was going through a renovation and had fewer pools and spas. Improvements made after the variance's approval have increased the number of pools and spas, thus increasing the cost of doing business.

Increasing the turnover rate to twelve hours will not ensure that the flow-through system provides clean water during the 15 hours of daily operation. The two pools are large, and the spas are not drained and cleaned between clients as required by NAC 444.484 (7). Mr. Begich has verified that the pools and spas are only drained and cleaned at the end of the day. The current pool code requires that pools have a six-hour turnover rate (NAC 444.152) and spas every 30 minutes (NA6 444.484) for recirculated systems.

Carson City Hot Spring, size of the pools and spas

- Pickaxe Pool, no jets: 38,568 gallons
- Big Pool, no jets: 37,500 gallons
- Frog Pool with jets: 9,222 gallons
- Minecart Pool, with jets: 6,500 gallons
- Indoor Soaking Pools, no jets, 600 gallons each.

The turnover rate is the number of hours required to completely recirculate the water in a public bathing or swimming facility through its filter and treatment systems, i.e., a complete water exchange. In a flow-through system, this rate is unknown. According to the Gage-Bidwell Law of Dilution (1926), water recirculating every six to eight hours will achieve 63% percent dissolution of contaminated pool water. Turnover is a key recommendation for pool operators when dealing with an accidental fecal release which is likely the primary source of high Cryptosporidium oocyst concentrations. Also, the Gag- Bidwell states that "*It can readily be demonstrated by computation and by experiment that seven turnovers are required to effect removal of 99.9% of the dirt present in the water of the pool when recirculation was started. At the end of the first turnover, the purification will be about 63%, after two turnovers about 86%, and after six turnovers 99.7%. To accomplish a purification of 99.99%, ten turnovers will be required*". However, the analysis above is based on two assumptions: (a) the pool is perfectly mixed, and (b) the filters are removing 100% of dirt from water passing through the filter media.

Turnover in gallons at current turnover rate. Current 6 hours

Size (Gallons)	63% (Gal)	Hours	86% (Gal)	Hours	99.7 % (Gal)	Hours
38,568	24,297	6	33,168	12	38,452	NA
37,500	23,625		32,250		37,387	
9,222	5,809		7,930		9,194	
6,500	4095		5590		6,480	
600 (Spa's)	378		516		598	

*NA, the pool is emptied at the end of each day.

Note: A typical six-person hot tub holds between 320-475 gallons of water.

DEGREE OF RISK TO PUBLIC HEALTH

There is a risk to public health in allowing this flow through to be increased from six hours to twelve hours or removing the turnover requirement entirely.

Proper pool circulation is one of the keys to maintaining a healthy sanitary pool or spa environment. Circulation moves pool water through the pool, removing particles and debris from the pools. The current six-hour turnover ensures that the water is substantially replaced at least twice a day. Increasing that rate to twelve hours or no turnover will promote the build-up of contaminants and pathogens in the pools.

EXCEPTIONAL AND UNDUE HARDSHIP

While the strict application of NAC 444.178(1) would require the Caron Hot Springs to increase costs and use equipment to add city water and maintain a six hour turnover provide by variance #694, the Division find that granting this variance would cause substantial determent to the public welfare and impair substantially the purpose of the regulation.

PUBLIC COMMENT RECEIVED

Notice of the hearing is scheduled to be posted on the Division of Public & Behavioral Health website at http://dpbh.nv.gov/Boards/BOH/Meetings/Meetings/ and at the 4150 Technology Way office in Carson City, NV. The

Division of Public & Behavioral Health is aware that the local regulatory authority Carson City Health and Human services does not support this variance. No other public comments have been received to date.

STAFF RECOMMENDATION

DPBH staff recommend denying the State Board of Health Case #721, Mark Begich, request for a variance to NAC 444.178(1) and maintain the variance provided by 2018.

PRESENTER

Teresa Hayes, Health Program Manager 3, Environmental Health Section

ATTACHMENTS

1. Revisiting the Gage–Bidwell Law of Dilution in Relation to the Effectiveness of Swimming Pool Filtration and the Risk to Swimming Pool Users from Cryptosporidium. By Lester P. Simmonds, Guy E. Simmonds , Martin Wood, Tim I. Marjoribanks and James E. Amburgey.

water

MDPI

Article

Revisiting the Gage–Bidwell Law of Dilution in Relation to the Effectiveness of Swimming Pool Filtration and the Risk to Swimming Pool Users from *Cryptosporidium*

Lester P. Simmonds [1], Guy E. Simmonds [1], Martin Wood [1,*], Tim I. Marjoribanks [2] and James E. Amburgey [3]

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2 School of Architecture, Building and Civil Engineering, Loughborough University, Ashby Road, Loughborough LE11 3TU, UK; t.i.marjoribanks@lboro.ac.uk
3 Civil and Environmental Engineering, University of North Carolina at Charlotte, 9201 University City Blvd., Charlotte, NC 28223-0001, USA; James.Amburgey@uncc.edu
* Correspondence: martin@poolsentry.co.uk

Abstract: The transfer of water from a swimming pool to the treatment location is key in determining the effectiveness of water treatment by filtration in removing turbidity and managing the risk from particulate material, including microbial pathogens, such as *Cryptosporidium* spp. A key recommendation for pool operators when dealing with an accidental faecal release (the likely main source of high *Cryptosporidium* oocyst concentrations in pools) is that the pool water should be filtered for at least six turnover cycles prior to use. This paper briefly outlines the theoretical basis of what has become known as the Gage–Bidwell Law of Dilution, which provides a basis for this recommendation, and extends the idea to account for the impact of filter efficiency. The Gage–Bidwell Law reveals that for each pool turnover 63% of the water resident in the pool at the start of the turnover period will have been recirculated. Building on this, we demonstrate that both filter efficiency and water-turnover time are important in determining filtration effectiveness and can be combined through a single parameter we term 'particle-turnover'. We consider the implications of the Gage–Bidwell Law (as referred to in the original 1926 paper) for the dynamics of the 'dirt' content of pool water, whether in terms of a specific particle size range (e.g., *Cryptosporidium* oocysts) or turbidity.

Keywords: *Cryptosporidium* oocyst; filtration; Gage–Bidwell Law; particle-turnover; pools; turbidity

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Citation: Simmonds, L.P.; Simmonds, G.E.; Wood, M.; Marjoribanks, T.I.; Amburgey, J.E. Revisiting the Gage–Bidwell Law of Dilution in Relation to the Effectiveness of Swimming Pool Filtration and the Risk to Swimming Pool Users from *Cryptosporidium*. *Water* **2021**, *13*, 2350. https://doi.org/10.3390/w13172350

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1. Introduction

Understanding the circulation of water in swimming pools is critical to managing the risk to bathers from microbial pathogens, such as *Cryptosporidium* spp. [1]. *Cryptosporidium* oocysts are not susceptible, in the timescales required, to residual biocides such as free chlorine (the C_t value for a 3 $\log_{10}$ reduction in oocyst viability for free chlorine at pH 7.5 and at 25 °C corresponds to a disinfection time of 10.6 days in pool water containing 1 mg L^{-1} free chlorine) and can only be controlled adequately in a pool plant room (i.e., external to the pool itself) by filtration, possibly supplemented by non-residual treatments such as UV or ozone [2]. Of particular concern is the large number (potentially > 10^8) of *Cryptosporidium* oocysts likely to be introduced into the pool water as a result of an accidental faecal release (AFR) by a bather [3,4]. There is a chance of infection from ingestion of just a single oocyst [5] and guidelines have been produced for managing this risk associated with AFRs [6].

The transfer of water from the pool to the water treatment plant (e.g., filtration system) via the re-circulation pipework is critical in determining the effectiveness of these controls and hence managing the risk to bathers. One key recommendation [6] is that the water in a pool subject to an AFR should be filtered for six turnover cycles (for pools using sand filters with a filtration velocity less than 25 m h^{-1}). In this context, a turnover cycle is the time taken for a volume of water equivalent to the entire pool volume to pass through the filtration and circulation system once [7]. As we shall demonstrate, this does not mean that all the water in a pool is subject to filtration in a single turnover cycle.

The question arises, why six turnover cycles? A justification was outlined in a trade magazine article by Croll [8], but the origins go back to a seminal report published 78 years previously in the *American Journal of Public Health* [9]. This reports the findings of a committee comprising members of the American Public Health Association and the Conference of State Sanitary Engineers (chaired by Stephen DeM Gage), which proposed a set of standards for the design, construction, equipment and operation of swimming pools. Many of the recommendations would be recognised in today's codes of practice, such as those issued by the UK Pool Water Treatment Advisory Group [10].

Section XVI of the report considers "Proportioning the water interchange for recirculation and flowing through pools" and is concerned with the purification of water by dilution or filtration as water is recirculated through a pool. The report points out that this purification process proceeds according to the Gage and Bidwell "law of purification by consecutive dilution", subsequently referred to as the Gage–Bidwell Law of Dilution. This law is presented in the form of an abstract of a paper in preparation at the time, which states that "at the end of the first turnover the purification [removal of the dirt present in the water of the pool when recirculation was started] will be about 63%". In other words, for each pool turnover 63% of the water resident in the pool at the start of the turnover period will have been recirculated. It is this law, proposed by Gage and Bidwell in 1926 in just 625 words, that has underpinned the recommendations in codes of practice for the clean-up of pool water following an AFR for almost a century (e.g., [6]).

However, the brief 1926 abstract gives little indication of the origins of the Gage–Bidwell Law of Dilution other than to state that it can be readily demonstrated by computation and experiment. To our knowledge, the paper associated with the Gage and Bidwell abstract has never been found, if indeed it was ever published. We attempt here to re-create the lost Gage and Bidwell paper and explore some of the implications that were suggested, but not developed. We explain the origin of the Gage–Bidwell Law of Dilution using solute (total dissolved solids or salt) and particles (turbidity or *Cryptosporidium* oocysts) as examples of contaminants, and we draw attention to some of the insights that were presented in the Gage and Bidwell abstract that have been largely overlooked but remain highly relevant today.

In addition to the cleaning up of a pool following a faecal contamination event, the other aspect of the performance of a pool filtration system that is of interest to designers, operators and those responsible for producing industry guidelines is the maximum concentration of contaminants, in particular turbidity, that is likely to result from the particles derived from anthropogenic sources (including dirt) washed off bathers in a pool [11]. This is likely to be dependent on the number and type of the bathers and pre-swim hygiene arrangements used in normal operation [12]. This was touched on in the 1926 abstract by reference to there being an equilibrium that exists between the input of dirt and the removal of dirt, according to the Gage–Bidwell Law of Dilution (though this theme was not developed further).

In this paper, we will demonstrate how the principles laid down in 1926 can be applied today to develop informed recommendations for the operation of swimming pools. These include the recommended maximum bathing load based on the performance of the pool treatment plant, including water circulation and filtration. For this, we use published data on fluctuations in turbidity in a very busy outdoor paddling pool over a summer period with large variation in bathing load [13].

In this paper, as a demonstration of the underlying principle, we will explore how the Gage–Bidwell Law of Dilution can be applied to two important aspects of pool operation: (i) management of an accidental release of particles into a pool as a result of an AFR; and (ii) management of bathing load and circulation rate to maintain the peak turbidity within an acceptable limit. We will conclude by considering the implications of these findings for the health and safety of pool users.

2. Materials and Methods

The underlying principles indicated by Gage and Bidwell [9] are demonstrated firstly using an empirical approach to consecutive dilution and then using a computational approach. This approach is then developed further to include filtration efficiency along with dilution in relation to removal of a specific particulate material following a single contamination event.

We then consider the ongoing removal of a continuous input of a contaminant, and the dynamic equilibrium that exists between the input and the removal of a contaminant (turbidity). We explore the maximum turbidity likely to be achieved if the design maximum bathing load for a pool is sustained (a) indefinitely or (b) for a finite period.

The data set of Stauder and Rodelsperger [13] provides a valuable opportunity to examine how the principles of the Gage–Bidwell Law of Dilution can be applied to model the dynamics of turbidity in a pool because (a) the assumption of good mixing is reasonable, and (b) the filter efficiencies are high enough (approximately 90% removal of turbidity when the pool is open), leaving fluctuation in bathing load as the main determinant of the observed fluctuations in water clarity. As there were very large differences between days in terms of bathing loads, this provides an ideal data set to test our understanding of how fluctuations in bathing load affect the hour-to-hour and day-to-day variation in pool water turbidity.

The key features of this pool were:

- Disinfection using chlorine gas (0.45 mg L^{-1} free chlorine in the pool water).
- pH adjustment (pH 7.0 in the pool water).
- Flocculant dosing approx. 0.05 mg L^{-1} Al as poly-aluminium chloride (PAC).
- Dual media filter (0.5 m sand depth, 0.7–1.2 mm grain size), (0.5 m anthracite depth, 1.4–2.5 mm grain size).
- Filtration velocity 35 m h^{-1}.

Removal efficiency for turbidity (NTU) was estimated as 0.9 during the period the pool is open, when using 0.06 mg L^{-1} Al coagulant as PAC, based on comparison of turbidity measurements at the filter inlets and outlets.

3. Results

3.1. The Gage–Bidwell Law of Dilution: Empirical Approach

The key to the origin of the Gage–Bidwell Law lies in the phrase 'by consecutive dilution' and is explained in the 1926 paper [9] as follows: "In a recirculation or flowing through pool in which the dirty or used water is continually being withdrawn and replaced by fresh or filtered water, purification of water proceeds by consecutive dilution. The first portion withdrawn from the pool will all be dirty water but, owing to the constant admixture of entering clean water with dirty water remaining in the pool, each succeeding portion of water withdrawn will consist of a decreasing proportion of dirty water mixed with an increasing proportion of clean water".

In the first instance, we consider that this experiment is carried out using three containers (or portions, referred to subsequently as parcels), each removing 1/3 of a pool volume. After three consecutive dilutions, one pool volume of water will have been removed and treated (one turnover cycle will have been completed). Importantly, we will make a key assumption (as made by Gage and Bidwell in the 1926 abstract) that this is a perfectly mixed pool so that when a container of pure water is returned to the pool it will instantly and completely mix with the water remaining in the pool. This will result in a uniform concentration of total dissolved solids (TDS) across the whole pool volume before the next container of water is removed. Table 1 shows the result of the three successive dilutions on pool water TDS (the same principle can be applied to particle concentration).

In this case, each container removes 1/3 of the total pool water volume, and one pool volume has been removed after three container-equivalents of water have been replaced.

Table 1. Effect on the average concentration of dissolved solids (or particles) by removing water from a pool one container-full at a time and replacing the water removed with the same quantity of pure water, thereby progressively diluting the water in the pool.

State	Cumulative Fraction of Pool Volume Removed	Average Concentration (C) in Pool Water after Mixing
Starting state	0	$C = C_o$
After first container	1/3	$C = (1 - 1/3)\ C_o$
After second container	2/3	$C = (1 - 1/3)\ (1 - 1/3)\ C_o$
After third container	1	$C = (1 - 1/3)\ (1 - 1/3)\ (1 - 1/3)\ C_o$

In this example, the average concentration remaining after one turnover (C) will be 0.296 (or 29.6%) of the concentration at the start of the turnover period (C_o), implying that 30% of the water resident in the pool at the start of the turnover remains in the pool after one turnover. Reworking the example above with two consecutive parcels each containing half the pool volume would have resulted in a corresponding value of 25%; four consecutive parcels each containing a quarter of the pool volume would have resulted in a corresponding value of 32%. The pattern is that as the number of parcels increases (and their size decreases) the percentage of water remaining untreated after one turnover increases towards some maximum value. Furthermore, the only way to ensure none of the water resident in the pool at the start of the turnover remains in the pool after one turnover would be to remove and replace all the water in the pool as a single parcel. This could be achieved by following the 'empty and fill' practice used in the early days of municipal pool management [14].

3.2. *The Gage–Bidwell Law of Dilution: Computational Approach*

The general pattern emerging from the empirical approach (Table 1) suggests that for the general case, where one pool volume is removed in N consecutive parcels, the average concentration of TDS in the pool after one pool volume of water has been treated (C_{pv}) is given by Equation (1):

$$\frac{C_{pv}}{C_o} = \left(1 - \frac{1}{N}\right)^N \quad (1)$$

The Gage–Bidwell Law is based on continuous (i.e., where N is a very large number) dilution of water taken from a perfectly mixed pool. As N is increased towards a very large number, the value of C_{pv}/C_o in Equation (1) converges to 0.368 (to three significant figures). In other words, 63.2% of the water present in the pool at the start of the turnover cycle has been treated at the end of the single turnover cycle, with 36.8% remaining untreated.

We can now go beyond what was stated in the Gage and Bidwell abstract to express the outcome of Equation (1) in terms of a continuous function to describe how the concentration C changes with the number of water turnovers (T). As N is increased to a very large number, each consecutive dilution is causing the concentration to change over an infinitesimal increase in turnover number: an amount which, in the notation of calculus, approximates to dC/dT.

Consider the change in concentration after the ith parcel of water has been removed and replaced. The concentrations after the (i − 1)th and ith parcels are given by Equations (2) and (3), respectively:

$$C_{i-1} = \left(1 - \frac{1}{N}\right)^{i-1} \quad (2)$$

$$C_i = \left(1 - \frac{1}{N}\right)^{i} \quad (3)$$

The change in concentration (ΔC) caused by the removal of the ith parcel is the difference between these as given in Equation (4):

$$\begin{aligned}\Delta C = C_i - C_{i-1} &= \left(1-\tfrac{1}{N}\right)^{i} - \left(1-\tfrac{1}{N}\right)^{i-1} = \left(1-\tfrac{1}{N}\right)^{i-1}\left(1-\tfrac{1}{N}-1\right) \\ &= \left(1-\tfrac{1}{N}\right)^{i-1}\left(-\tfrac{1}{N}\right)\end{aligned} \tag{4}$$

The corresponding fractional change in turnover (ΔT) is given by Equation (5):

$$\Delta T = \frac{1}{N} \tag{5}$$

The rate of change in concentration ($\Delta C/\Delta T$) tends to dC/dT when N is very large, and is given in Equation (6) (see also Equation (2)):

$$\frac{dC}{dT} = \frac{\left(1-\tfrac{1}{N}\right)^{i-1}\left(-\tfrac{1}{N}\right)}{\tfrac{1}{N}} = -\left(1-\frac{1}{N}\right)^{i-1} = -C \tag{6}$$

This reveals an interesting feature of the dilution process: when the circulation of water is expressed in units of turnover, then the amount removed in each dilution (dC/dT, when N is large) is numerically equal to the concentration at the time (both being $(1-1/N)^i$). Therefore, we can write Equation (7):

$$\frac{dC}{dT} = -C \tag{7}$$

Separating and integrating Equation (7) from the initial condition $C = C_o$ when $T = 0$ gives Equation (8):

$$\frac{C}{C_o} = \left(\frac{1}{e}\right)^{T} = e^{-T} \tag{8}$$

where e is the Euler number (2.71828 . . .), one of the most important fundamental and natural numbers in mathematics. This exponential decay equation indicates that each turnover will reduce the concentration by $1/e$ which, to three significant figures, is the Gage and Bidwell value of 0.368.

Equation (8) describes the removal of a contaminant from a continuous flow stirred-tank reactor (CSTR), which is a well-established principle in chemical engineering (analogous to Equation (1) of Alansari et al. [15]). The usefulness in the context of swimming pools depends on the validity of the assumption that pools are perfectly mixed. Alansari et al. [15] provided a rare example of testing this assumption by analysing the residence time distribution of electrical conductivity following either a step-change or a slug-dose of a salt solution (KCl) passing through scale models of pools with different flow configurations. Alansari et al. [15] concluded that pools with widely differing configurations of inlets and outlets had residence time distributions (RTD) very similar to that expected for a CSTR, with the exception of there being short-lived spikes in the very early stages of the distribution depending on the small proportion of contaminant that was short-circuiting from the inlets to outlets. Modelling of a pool using computational fluid dynamics (CFD) by Cloteaux et al. [16] also led to the conclusion that the residence time distribution obtained from the CFD model of a simple rectangular pool with inlets at the shallow end and outlets (sumps) in the deep end was very similar to that expected for a CSTR. This suggests that the underlying principles of the Gage and Bidwell analysis are a good first approximation of pool behaviour with respect to the removal of particles over timescales of interest (several turnover cycles).

3.3. The Role of Filter Efficiency in Contaminant Removal

One application of the Gage–Bidwell Law of Dilution is to investigate the removal of *Cryptosporidium* oocysts from a well-mixed pool following an AFR. Though *Cryptosporidium* was not a known hazard in pools at that time, in the 1926 "Standards for design, construction, equipment and operation" the authors [9] did apply the Gage–Bidwell Law of Dilution to consider water purification in terms of the removal of dirt by filtration. The Gage and Bidwell abstract [9] stated that "It can readily be demonstrated by computation and by experiment that 7 turnovers are required to effect a removal of 99.9% of the dirt present in the water of the pool when recirculation was started. At the end of the first turnover the purification will be about 63%, after two turnovers about 86%, and after six turnovers 99.7%. To accomplish a purification of 99.99% 10 turnovers will be required".

There is a clear legacy of this conclusion in the current guideline that six turnovers are needed to reduce the amount of *Cryptosporidium* oocysts remaining in the pool to an acceptable level following an AFR [6]. In this context, we can use Equation (8) to deduce that 99.7% of water would be treated in six turnovers, which would amount to 1.5 m^3 of untreated water remaining in the case of a 500 m^3 pool. As an example of the practical implications, this untreated water might still contain 300,000 oocysts if the pool is well-mixed and if there had been an input of 10^8 oocysts prior to the six turnovers [17].

However, the analysis above is based on two assumptions: (a) the pool is perfectly mixed; and (b) the filters are removing 100% of dirt from water passing through the filter media. The Gage and Bidwell abstract acknowledged the latter and considered the consequence of filtration being less than 100% efficient. Following the imagined thinking of Gage and Bidwell, we can consider the effect of reduced filter efficiency by repeating the dilution experiment as shown in Table 1, but this time replacing only part of the water removed from the pool at each dilution with pure water (so that some fraction of the salts, or solids, in the water taken from the pool is returned to the pool).

Let the fraction of the water in each successive container that is replaced by pure water be termed E. This is analogous to the filter efficiency: a value of 1 represents a filter removal efficiency of 100%. So now we are not only removing the salts (or solids) present in volume 1/N at each dilution but are also returning (1 − E)/N back to the pool. Therefore, Equation (1), which describes the fraction remaining in the pool after one turnover, now becomes Equation (9):

$$\frac{C_{pv}}{C_0} = (1 - \frac{1}{N} + \left(1 - \frac{E}{N}\right)^N = \left(1 - \frac{E}{N}\right)^N \quad (9)$$

Following the same process that led to the derivation of Equation (3), this further leads to Equation (10):

$$\frac{C}{C_0} = e^{-ET} \quad (10)$$

Figure 1 shows examples of how the time required for cleanup of particles (such as turbidity or *Cryptosporidium* oocysts) is extended if the filter efficiency is less than 100%. The selected examples range from E = 0.9, which corresponds to the value assumed by PWTAG [10] as the case for a well-managed pool, to E = 0.2, which Gregory [4] suggested to be a typical value for a pool with ineffective coagulation. This covers the range of efficiency reported by Lu and Amburgey [18] in a study of the impact of coagulants and filtration velocity on the removal of 4.5 μm polystyrene microspheres using sand filtration. The curves shown in Figure 1 accord with the statement made in the Gage and Bidwell abstract that "If the filters have an efficiency of only 50%, the effect will be the same as though the recirculation system were only half the size". However, there have been very few studies on the efficiency of swimming pool filters in removing dirt (particles) in operational pools, so it is not widely appreciated that this is an aspect of the performance of pool water treatment that can be as important as the water-turnover time with respect to particle removal.

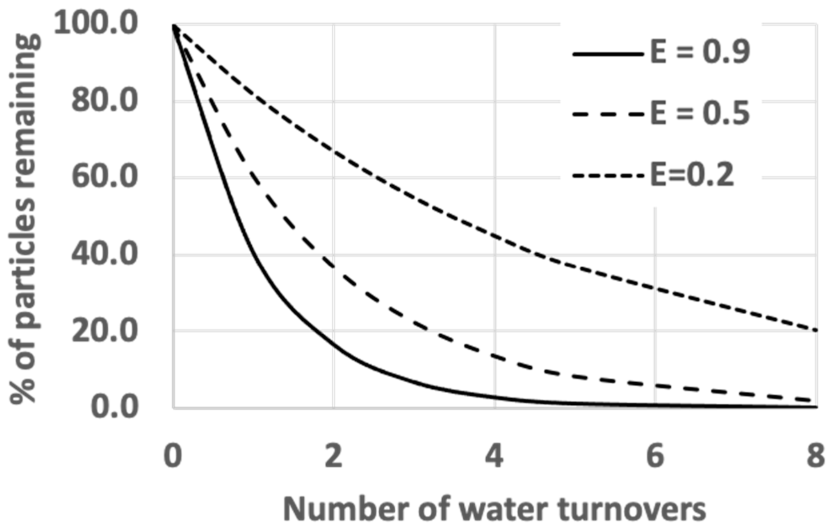

Figure 1. Effect of filter efficiency (E) on the removal of dirt particles from pool water (expressed as percentage of particles remaining) following successive water-turnover cycles, based on the Gage–Bidwell Law of Dilution.

Given the importance of the combination of water-turnover time and filter efficiency in determining the rate of removal of particles from a pool, it is useful to combine these two parameters into a single key performance indicator that provides an overall measure of the effectiveness of the filtration system. Therefore, we propose the term 'particle-turnover time', T_p, as distinct from the water-turnover time, $T_w = V/Q$, given by Equation (11):

$$T_p = \frac{V}{QE} = \frac{T_w}{E} \tag{11}$$

where V is the pool volume (m^3), Q is the circulation rate ($m^3\ h^{-1}$), and E is the fractional removal of either turbidity (NTU) or particles of a given size class from water in a single pass through the filter.

Whereas the turnover time for water (T_w) is the time it takes 63.2% of the water in a well-mixed pool to be removed, the particle-turnover time (T_p) is the time it takes 63.2% of particles to be removed. An example of this is illustrated later by diurnal measurements of turbidity (Section 3.5). There is an approximately exponential decrease in turbidity once the pool is closed, where the exponent is the particle-turnover time.

3.4. *Application of the Gage–Bidwell Approach to Modelling the Peak Turbidity of Pool Water*

So far, we have limited the discussion of the applications of the principles of the Gage and Bidwell abstract to the removal of a specific particulate material following a single contamination event (such as an AFR). We now consider the implications for the ongoing removal of a continuous input of a contaminant, and the dynamic equilibrium that exists between the input and the removal of a contaminant. We will explore this using the input and removal of turbidity from pool water. In this context, a key performance indicator of interest to a pool operator is the peak turbidity likely to be achieved. This has practical significance in managing the risk of a swimmer drowning, as it determines whether a lifeguard will be able to see the whole of the pool floor from a single point at poolside [6]. The prediction of the peak turbidity is complex, because it depends on highly variable factors that determine the temporal pattern of input of contaminants to the pool, which will depend primarily on the amount and distribution of bathing load throughout the day, and the nature and hygiene of the bathers [2].

An important concept introduced by Gage and Bidwell in their 1926 abstract [9] was that there will be some dynamic equilibrium between the rate at which turbidity (dirt) is added and the rate at which it is removed. In their words, "If the pool is used regularly by bathers further increments of dirt will be introduced into the water daily, and the removal of each successive daily increment will proceed according to the law. The result of the addition of such daily increments will be an increasing accumulation of dirt in the water up to a certain point, after which the dirt content of the pool water will remain practically constant. The amount of this accumulation depend[s] upon the rate of turnover of the pool and is also dependent upon the efficiency of the filters". This simple concept of the 'dirt content' of pool water moving towards some equilibrium has rarely been applied to understanding the factors controlling the peak turbidity likely to be achieved in a pool at times of peak bathing load. Though it is beyond the scope of this paper to consider modelling the detailed time course of turbidity in relation to bathing load (as done by Stauder and Rodelsperger [13] using a differential continuity equation), we will show how the principles outlined by Gage and Bidwell [9] can be applied quite simply to achieve two things:

1. To establish the equilibrium turbidity likely to be achieved if a constant bathing load (in terms of numbers of bathers per hour) is maintained indefinitely.
2. To establish the maximum turbidity likely to be achieved if a constant bathing load is sustained for a finite time that is too short for the equilibrium to be achieved.

This provides a useful tool for assessing the performance of a pool in terms of the likely peak turbidity, and which could also be used to inform those responsible for developing guidelines for pool operation.

3.4.1. Modelling the Maximum Turbidity Achievable If the Design Maximum Bathing Load for a Pool Is Sustained Indefinitely

The principle stated by Gage and Bidwell in 1926 [9] using the term 'dirt', but applied here to turbidity, is that if a constant input of turbidity is maintained indefinitely, then the pool water turbidity will rise until the rate of removal of turbidity by filtration (which rises as the turbidity of water being delivered to the filter increases) matches the rate of input.

Turbidity is measured by nephelometry [6], based on the measurement of scattered light by particles in a sample, and expressed in units of nephelometric turbidity unit (NTU). The intensity of the scattered radiation is related to the intensity of the incident radiation and the concentration of particles that are causing the scattering [19]. In this analysis, we shall consider the turbidity of water expressed in NTU as a concentration resulting from the quantity of turbidity-forming particles introduced by bathers. Therefore, the rate at which turbidity is removed is equal to the product of the rate of delivery of turbidity-forming particles to the filter (i.e., the pool water NTU multiplied by the circulation rate, Q, in $m^3\ h^{-1}$) and the filter efficiency (expressed in terms of the fraction of turbidity that is removed in a single pass through the filter, E).

The hourly input of turbidity will be the product of the number of bathers entering the pool per hour (B) and the quantity of turbidity-forming particles added on average by each bather (K_p). If at equilibrium the rates of addition and removal of turbidity are equal, the equilibrium turbidity (C_e) is given as in Equation (12):

$$C_e = \frac{B\,K_p}{Q\,E} \tag{12}$$

In the analysis presented here, the values of B and Q are unequivocal, and the assumption is that they are kept constant. However, the values of K_p and E are more ambiguous and require further discussion.

The value of E depends on a number of factors, including the particle size [7], and would be expected to have a lower value if being used in the context of *Cryptosporidium* oocyst removal than for the removal of turbidity [7]. The value of E may also change with time, due to fluctuations during the course of a day (as the dirtiness of the water changes), and possible changes in performance of the filter media over periods of several days during the backwash cycle [20]. However, in the context of establishing the equilibrium turbidity during a period of constant bathing load the value of E for a filter would be expected to be relatively stable during the period that the equilibrium is being approached, assuming that other factors that affect the efficiency (e.g., coagulant dosing rate and the filtration velocity) remain constant.

In the context of turbidity, filtration efficiencies of 0.9 have been reported [13] for a pool with dual media anthracite/sand filters and coagulant (PAC) dosing optimised to minimise the measured filtrate turbidity. Where coagulation is poor or absent, filtration efficiencies of 0.2 (or less) are likely [4,18]. We shall examine the predicted equilibrium turbidity in scenarios used in Figure 1, where the filter efficiencies for turbidity removal during periods of protracted heavy bathing load will be E = 0.9, 0.5 or 0.2. This covers the range that most swimming pools are likely to be operating in.

There is little information on the likely values for the average amount of turbidity-forming material introduced per bather into pool water. Two approaches have been used to obtain this information. The first is to measure the rise in turbidity in a small body of water (e.g., a spa) following entry of by a known number of bathers, where the input per bather is calculated by dividing the rise in NTU by the number of contributing bathers per m^3 of water. This method was used by Amburgey (personal communication, 2020) who reported an average K_p value of 0.65 NTU (bather $m^{-3})^{-1}$. A variation to this approach might be to collect shower water and measure the recovery of particles from individuals, as done by Keuten at al [21], although the range of values for the sloughing of turbidity-forming material was not reported. An alternative method was used by Stauder and Rodelsperger [13], who used the continuity form of Equation (10) to model the diurnal fluctuations in turbidity from the differences between the rates of input and removal of turbidity, based on the assumption of a well-mixed pool. The parameters affecting the modelled time course of turbidity were the circulation rate (Q), the filter efficiency (E), the known fluctuation in bathing load and the average K_p. As all parameters except K_p were known, values of K_p for each day were obtained by finding the values that gave the best fit between the modelled and measured time course of NTU. This resulted in values ranging from 0.25 to 0.5 NTU (bather $m^{-3})^{-1}$. However, it should be noted that Stauder and Rodelsperger [13] reported the daily visitor number, and it may be that not all the visitors entered the pool; therefore, these values will underestimate K_p. It should also be noted that as this was a paddling pool, not all bathers would be fully immersed, which is likely to reduce the inferred value for K_p. In the scenarios we consider below, we will use values of 0.25 or 0.65 NTU (bather $m^{-3})^{-1}$ to represent the range from 'clean' to 'dirty' bathers.

The application of Equation (12) as a guide for pool operators is illustrated by Figure 2, which shows values for the equilibrium (i.e., the maximum possible) turbidity for several pool scenarios. To facilitate a comparison between very different pools, the x-axis shows the ratio of the number of bathers entering the pool to the volume (m^3) of water being treated (i.e., B/Q from Equation (12)). For example, a pool with 100 bathers h^{-1} entering the pool with a water circulation rate of 200 m^3 h^{-1} would return a value of 0.5 bathers m^{-3} circulation, which is the same value as for a spa with 10 bathers h^{-1} entering the spa with a water circulation rate of 20 m^3 h^{-1}. To put the range of *x*-axis values into context, a leisure pool with an average depth of 1.5 m operating at maximum bathing load (allowing 4 m^2 water area per bather) and a 3 h water-turnover time would have a value of 0.5 bathers m^{-3} circulation.

The possible scenarios in Figure 2 also cover a range of filtration efficiency (E = 0.9, 0.5 or 0.2) [7]. These are shown in combination with relatively dirty or relatively clean bathers using K_p = 0.65 or 0.25 NTU (bather $m^{-3})^{-1}$ over the range of values on the x-axis likely to encompass most pools. With relatively good filtration (E = 0.9), the equilibrium turbidity value (achieved after a very long time of bathers entering the pool at a steady rate) will only just reach 0.5 NTU at a value of 1.0 bathers m^{-3} circulation with dirty bathers. However, pools with less effective filtration (E = 0.5) are at risk of the turbidity exceeding 0.5 NTU at a value of 0.5 bathers m^{-3} circulation when the bathers are dirty. Pools with relatively poor filtration (E = 0.2) are predicted to have excessive turbidity after prolonged periods of maximum bathing load at a value of 0.4 bathers m^{-3} circulation even with the cleanest bathers.

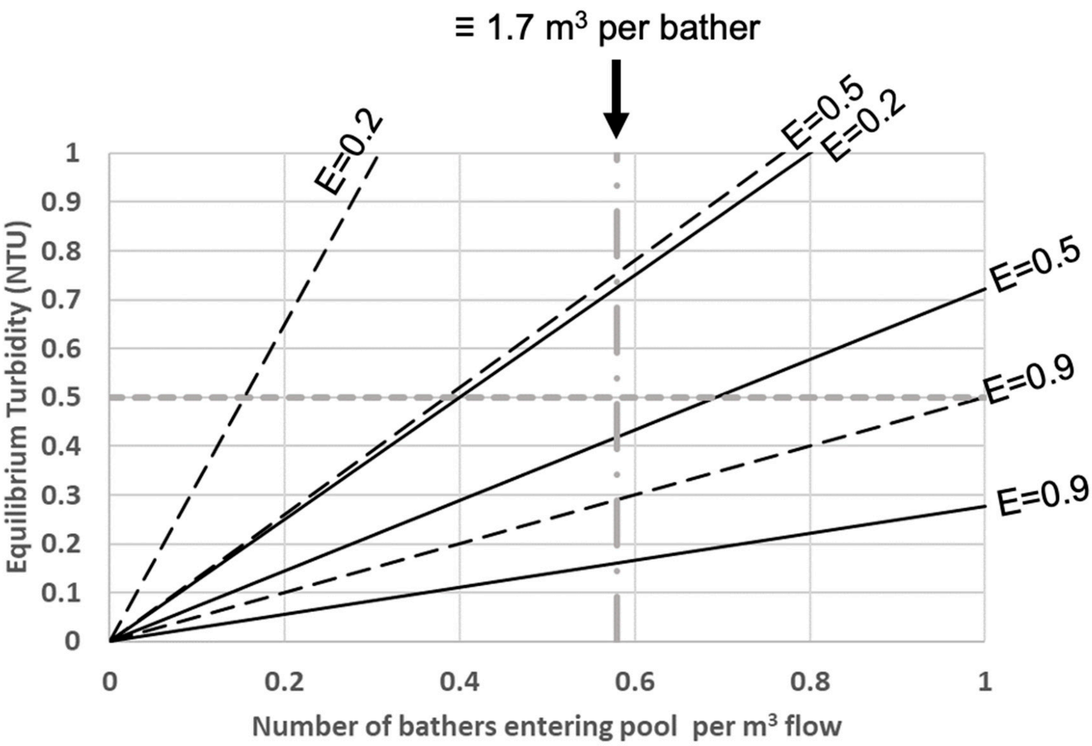

Figure 2. Effect of the number of bathers entering the pool per unit volume of water flow through the filtration system on pool water equilibrium turbidity (NTU), assuming different dirt loadings per bather (solid line K_p = 0.25 NTU (bather $m^{-3})^{-1}$; dashed line K_p = 0.65 NTU (bather $m^{-3})^{-1}$) and different filtration efficiencies (E). The x-axis is the ratio of the number of bathers entering the pool to the volume (m^3) of water flow through the filtration system (i.e., B/Q from Equation (12)) and value of 0.58 is equivalent to 1.7 m^3 water flow through the filtration system per bather.

The concept of the number of bathers per m^3 of water treated by filtration (x-axis Figure 2) is already established in pool operation guidelines. For example, the guidelines for pool operation in the UK [10] recommend that where the circulation rate is limited by the design of the pool, the maximum bathing load for the pool should be calculated from Equation (13):

$$\text{Maximum bathing load (bathers per hour)} = Q\ (m^3\ h^{-1})/1.7 \quad (13)$$

This value of 1.7 m^3 circulation/bather is equivalent to an x-axis value in Figure 2 of 0.58 bathers m^{-3}, shown by the vertical dashed line. Provided the filtration is relatively good (E = 0.9 in this case), this upper limit guideline maintains equilibrium turbidity of the pool water within an acceptable range (no more than 0.3 NTU even with very dirty bathers) in the case where the maximum bathing load is sustained indefinitely.

Note also that the model predicts that an upper limit guideline of 0.58 bathers m^{-3} (equivalent to 1.7 m^3 water flow through the filtration system per bather) will result in only slight exceedance of the upper acceptable limit of 0.5 NTU, even with dirty bathers, i.e., K_p = 0.65 NTU (bather $m^{-3})^{-1}$, and relatively poor filtration (E = 0.5). In this respect, this guideline [10] is necessarily cautious in that it will maintain acceptable water quality even in pools with relatively dirty bathers and relatively poor filtration performance. Recommendations for water-turnover times for pools may also need some contingency for pools where the water volume behaves as a number of separate compartments and where the ratio of water circulation to bather number within a compartment could be rather less than the overall average for the pool.

3.4.2. Modelling the Maximum Turbidity Achievable If the Design Maximum Bathing Load for a Pool Is Sustained for a Finite Period

The preceding analysis considered the turbidity reached in swimming pool water when in a state of equilibrium achieved in the case where bathers continue to enter the pool indefinitely at a constant rate. This leads to the question whether bathing loads are ever sustained for long enough for the equilibrium turbidity to be achieved. For example, the measured diurnal courses of turbidity for the heavily used 690 m^3 paddling pool studied by Stauder and Rodelsperger [13] showed large fluctuations in turbidity during the day, with the peak values generally appearing as sharp mid-afternoon spikes rather than approaching a plateau. This suggests that equilibrium turbidity values were a long way from being approached in this particular case.

Modelling using the Gage–Bidwell principles described above involves essentially the same problem as modelling the removal of *Cryptosporidium* oocysts following an AFR using Equation (10). The latter describes the transition from some initial concentration (C_o) to the special case of the final equilibrium concentration being zero. However, as we are now concerned with the accumulation of turbidity-causing particles from some initial starting condition (C_o) to a final non-zero equilibrium turbidity (C_e), Equation (10) can be written in the following more general form:

$$\frac{C}{C_e - C_o} - C_o = 1 - e^{-ET} = 1 - e^{-t/T_P} \quad (14)$$

where the left side of Equation (14) represents the concentration of particles (or the NTU) expressed as a fraction of the step change from the original concentration (C_o) to the final equilibrium concentration C_e. Just as with the removal of *Cryptosporidium* oocysts, we see that after one particle-turnover time we have reached 63.2% of the final result of the step change and reached 99.7% of the change after six particle-turnovers.

Hence, the progress towards the equilibrium turbidity under conditions of constant bathing load is related to the number of particle-turnovers, irrespective of pool size. The implications are illustrated in Figure 3, which shows, for three filtration efficiencies, how rapidly the turbidity changes towards a new equilibrium value following a change in bathing load. For example, with relatively good filtration (E = 0.9), 90% of the change towards the new equilibrium turbidity occurs after 2.6 water-turnovers. Hence, for a spa with a 10 min water-turnover time, 90% of the transition towards the equilibrium NTU is predicted to be achieved in 26 min. This suggests that a spa is quite likely to approach the equilibrium NTU predicted for the maximum allowable bathing load. However, for a leisure pool with 1.5 m average-depth and 3 h water-turnover time, it would take 7.8 h of continuous maximum bathing load for the turbidity to reach 90% of the change from C_o to C_e. This explains why time courses of turbidity for leisure pools typically show short-term ‘spikes’ at times of peak bathing load, rather than approaching a plateau, because the fluctuations in bathing load are too rapid for equilibrium states to be approached.

If the filters were only removing 50% of the turbidity from water passing through the filters, the equilibrium turbidity would be higher, but the time taken to reach 90% of the change from C_o to C_e would increase to 47 min for the spa and 14 h of continuous bathing load for the pool. The implication is that in practice it is only in pools with very short water-turnover times (such as spas and paddling pools) that the turbidity is ever likely to approach the equilibrium value for the maximum instantaneous bathing load. Pools with water-turnover times longer than 2 h would not be expected to approach the equilibrium turbidity for the maximum bathing load that was used as the basis of the nomogram shown in Figure 2.

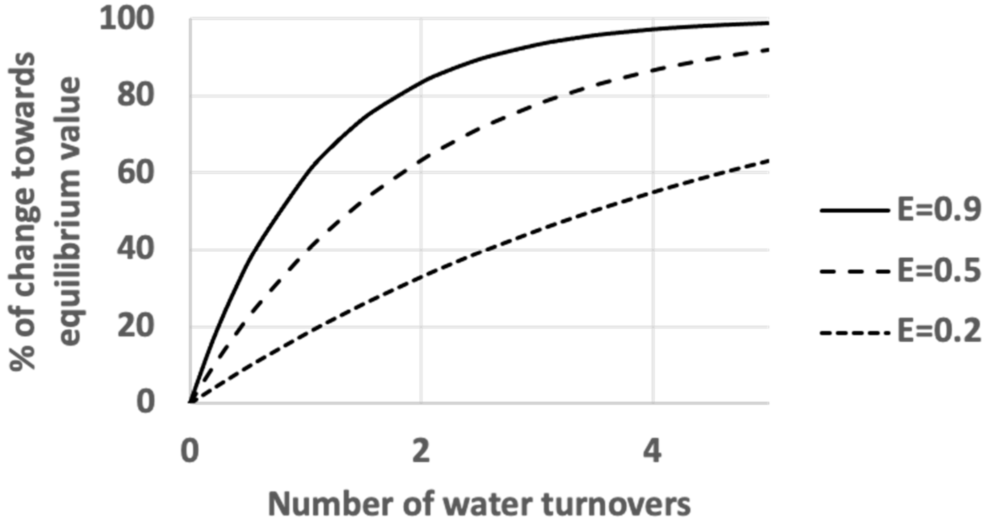

Figure 3. Effect of filtration efficiency (E) on the rate at which turbidity approaches equilibrium following a change in bathing load as the number of water-turnovers increases.

It should be noted that Figure 3 can also be applied to predict of the rate of reduction in turbidity during a recovery period when bathers are absent from the pool, and where the turbidity of the pool water will fall from its value at the start of the recovery period towards near zero. For example, using Equation (14), a heavily used water park pool with a 2 h particle-turnover would expect a 40% reduction in turbidity after just 1 h of recovery time, increasing to 63% and 78% removal of turbidity after 2 and 3 h, respectively. The implication is that for a pool with good filtration there is little benefit in terms of particle removal of recovery periods longer than a couple of turnovers.

3.5. Modelling Observed Time Courses of NTU

Stauder and Rodelsperger [13] presented data showing the time course of turbidity over a 20-day period for a very busy outdoor paddling pool with large day-to-day variation in bather number. Stauder and Rodelsperger [13] also provided information on daily bather numbers (taken from their Figure 1), and so in order to model diurnal fluctuation in NTU we had to generate a bather frequency during the course of each day. To do this, we assumed that every day had the same time course of relative bathing load during the day, and that the relative bathing loads assigned to each hour period increased seven-fold from the first hour the pool opened to the period leading up to the time of peak turbidity. The temporal pattern of relative bathing loads was then scaled by the daily bather number to generate values for the numbers of bathers entering the pool during each hour.

The dashed line in Figure 4 shows the measured values of turbidity (NTU) during a week where there was a wide range of daily bather numbers. The data indicate that at night the turbidity values fall to <0.05 NTU, and then rise more or less steeply once the pool opens (depending on the bather numbers). The data indicate that generally a sharp peak occurs before the turbidity decreases once the bathing load falls, with turbidity decreasing particularly rapidly when the pool is closed.

The progress of turbidity (NTU) was modelled on an hourly basis using Equation (14) to predict the transitions in turbidity each hour. C_o was the turbidity value (NTU) at the end of the preceding hour, and C_e was calculated using Equation (12), based on the number of bathers entering the pool that hour and an assumed value for the turbidity input per bather. With a water-turnover time of 1.06 h and a filter efficiency of 0.9, Equation (14) predicts that in 1 h there will be 57% of the transition from C_0 to C_e. In this way the diurnal course of turbidity (NTU) was predicted, as shown by the solid line in Figure 4.

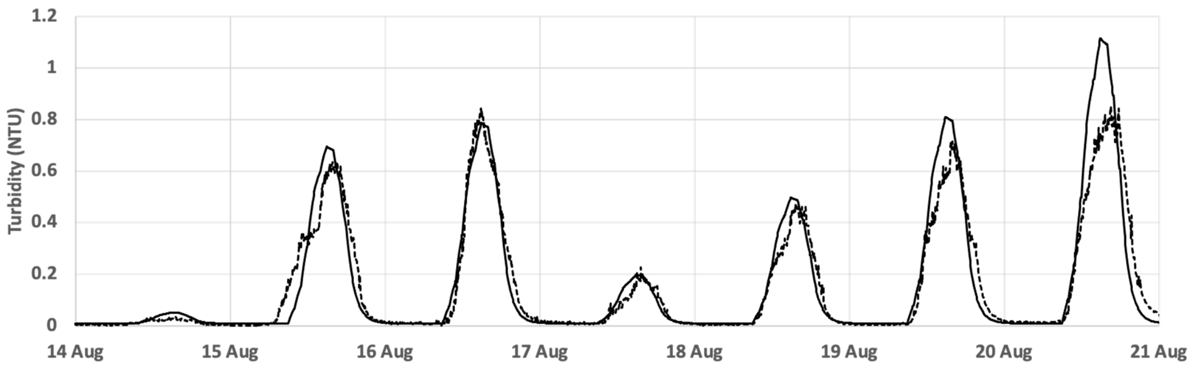

Figure 4. Comparison of the measured time course of turbidity (NTU) (dashed line) over 7 days with the prediction (solid line) made using Equations (12) and (14) and with values of K_p = 0.35 NTU (bather $m^{-3})^{-1}$, T_w = 1.06 h, and E = 0.9. The number of bathers entering the pool each hour was derived from the recorded daily bather numbers, and an assumed frequency distribution during the opening hours. Based on data of Stauder and Rodelsperger [13].

One key assumption made in this modelling exercise was that the temporal pattern of relative bather frequency was the same on all days. The second assumption was that the average turbidity (NTU) input per bather was the same at all times. This value was adjusted to optimise the fit of the modelled values to the measured values with the resulting 'best fit' value being 0.35 NTU (bather $m^{-3})^{-1}$. Despite these critical assumptions, the modelled time courses showed good agreement with the measured values and predicted the peak daily turbidity values to within 10%.

One of the purposes of carrying out these simulations was to predict the peak daily turbidity values for a pool and to compare them with the maximum observed values each day, to see whether this key performance indicator was predictable. Figure 5, based on the 21 consecutive days of data presented in Figure 1 of Stauder and Rodelsperger [13], shows the empirical relationship between daily bathing load and the measured peak turbidity values over a wide range of daily bather numbers. The observed peak turbidity (NTU) value was approximately proportional to bathing load. This would be expected if the days were similar in terms of the values of K_p, E, T_w and the temporal pattern of bather frequency, but differed only in the daily bather number, which would act to 'scale' the peak turbidity value.

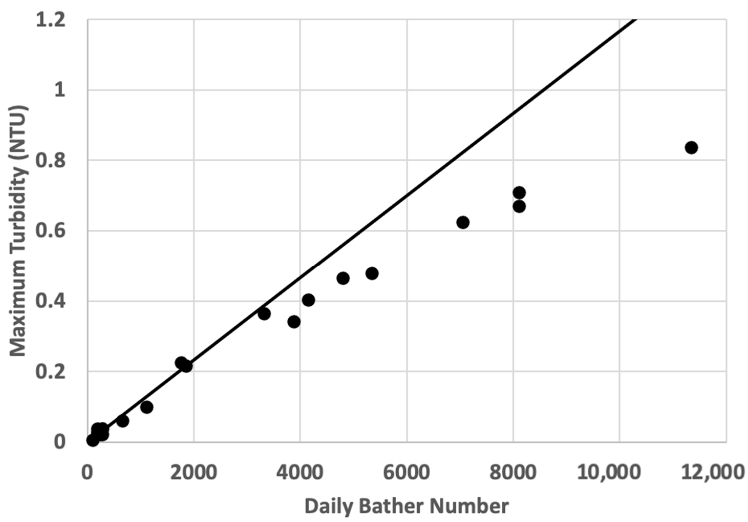

Figure 5. Empirical relationship between daily bathing load and the measured peak turbidity (NTU) over a wide range of daily bather numbers, based on the 21 consecutive days of data presented in Figure 1 of Stauder and Rodelsperger [13]. The solid line shows the comparison with the peak turbidity if the turbidity was at equilibrium with the peak bathing load (Equation (12)).

The solid line in Figure 5 shows the equilibrium turbidity values that were predicted using Equation (12), corresponding to the peak mid-afternoon bathing loads. It is seen that the observed peak turbidity fell short of the equilibrium turbidity values, which is also indicated by the absence of any evident plateauing of turbidity (NTU) values during the busiest periods (Figure 4). However, because in this example the water-turnover time was relatively short (1.06 h) there were sufficient turnover times during the busiest periods for the peak turbidity (NTU) values to rise to >50% of the equilibrium turbidity values.

3.6. Public Health Implications

This paper has demonstrated a number of potential applications of a simple model of particle removal from swimming pools based on the underlying principles and assumptions in the Gage and Bidwell model of "water purification by consecutive dilution" (Gage–Bidwell Law of Dilution). These principles were originally presented as an early attempt to provide scientific underpinning to the design and operation of swimming pools [9]. Our paper has shown that such a relatively simple model can be used to identify the key performance indicators for assessing the effectiveness of pool filtration, and also to assist in the development of well-informed guidelines for pool designers and pool operators. Examples include:

- Prediction of the time it takes to achieve satisfactory removal of a contaminant (e.g., *Cryptosporidium* oocysts) following a single contamination event.
- Prediction of the maximum equilibrium concentration of a contaminant under conditions of a steady input of the contaminant (we considered the maximum turbidity achieved under conditions of a prolonged constant bathing load).
- Prediction of the amount of water that should be circulated per bather to ensure that water clarity remains excellent, even when there is a very prolonged period when bathers are entering the pool.
- Prediction of the peak turbidity likely to be achieved in practice from knowledge of the distribution of bathing load during the day.

All of these predictions depend critically on the water-turnover time (which is widely used as a key performance indicator for pools). However, also of importance is the filtration removal efficiency, a parameter which is rarely measured, and can vary widely in swimming pool filtration systems (e.g., [18]). Our analyses indicate very clearly that it is the combination of the water-turnover time (T_w) and the filtration efficiency (E) that provides the best overall key performance indicator of the effectiveness of filtration in swimming pools. We propose a formalisation of this concept in a new combined term, particle-turnover time ($T_p = T_w/E$), which could provide the basis for assessing the health and safety risks associated with particulate material in pool water. However, this requires the development of a practical methodology for assessing the effectiveness of filtration in operational pools, which is not generally available at present, but which might be based on the use of turbidity measurements or particle counting [7].

Another application of this modelling is to assess the extent to which recovery periods with no bathers contribute to the removal of the recently added 'dirt' from bathers. Analysis of the data in Figure 5 showed that by the time the pool was closed, 88% of the turbidity introduced by bathers had already been removed by filtration. This value increased to 93% and >97% at 1 and 3 h, respectively, after the pool had closed. This suggests that overnight recovery plays only a relatively small role in the removal of recently added dirt from bathers.

The shallow paddling pool studied by Stauder and Rodelsperger [13] was an extreme case of a pool with a very high bathing load relative to the pool volume. This provided an ideal data set for testing the Gage–Bidwell Law of Dilution in practice. Both the measurements and the modelling showed that even though the filters were very efficient, the 1.06 h water-turnover time was not sufficient to maintain the peak turbidity below the 0.5 NTU acceptable limit during days when there were more than 6000 bathers in the 690 m^3 of water (Figure 5).

Consider now the case where the ratio of daily bather number to pool volume is more typical of a 25 m leisure pool, where the pool has the following attributes:

- Depth ranging from 1–2 m (average depth 1.5 m).
- 4 m^2 pool area allowed per bather at maximum bathing load following the UK guidelines [10], i.e., each bather occupies 6 m^3 of water on average.
- 3 h water-turnover time.
- Average bathing time of 0.75 h.

If such a pool was operating continuously at maximum bathing load, then there would be 1.5 m^3 of water treated per bather. This corresponds to a value of 0.67 bather m^{-3} for the *x*-axis of Figure 2, which would imply that with relatively good filtration of E = 0.9 [10] the maximum possible turbidity would be maintained below 0.4 NTU, even with relatively dirty bathers (0.65 NTU (bather $m^{-3})^{-1}$. With poorer filter efficiency (E = 0.5), the turbidity after very prolonged maximum bathing load would just exceed 0.6 NTU (i.e., slightly above the recommended upper limit) with relatively dirty bathers. With any reduction in the period of the maximum bathing load during each day (e.g., only two swim sessions, each of 3 h duration) the resulting maximum turbidity would be expected to be no more than 0.4 NTU.

3.7. Conclusions

We can conclude that, with the exception of pools with extensive shallow areas and long periods of near maximum bathing loads (based on UK guidelines), it would not be expected for leisure pools operating at near maximum bathing loads for prolonged periods to have water clarity issues due to any deficiency in the circulation/filtration system provided that (a) the filtration system is at least 90% efficient (E = 0.9) and (b) the water-turnover time was around the maximum recommended by industry guidelines [10]. With these conditions fulfilled, the above example shows that the maximum turbidity expected after 6 h of continuous maximum bathing load would be around no more than 0.4 NTU. There are indications [18] that filtration efficiencies in swimming pool filters can fall below the 90% values assumed in some of the treatment and quality standards [10]). However, there is a dearth of information on performance of filtration systems in operational pools. If, in practice, filtration efficiencies in swimming pools are much lower than this (which could be, for example, due to inadequate backwashing of filters or inadequate coagulation, insufficient filter depth, or excessively high filter loading rates), then this would be expected to cause water clarity to fall outside the acceptable range (as indicated in Figure 2). Though such a deficiency could perhaps be compensated for by increased turnover of water, it would be more appropriate to address any issues resulting in poor filtration, such as the effectiveness of the coagulation/filter aids, filter upgrades or the adequacy of backwashing procedures [7]. It should also be noted that establishing that the filtration is effective with respect to turbidity control does not necessary imply effective removal of *Cryptosporidium*, as the removal of particles the size of *Cryptosporidium* oocysts can be less effective than the sub-micron particles causing turbidity [7]. Furthermore, our model assumes irreversible removal by filtration and there is the possibility that previously-trapped oocysts may be released back into the pool (e.g., following backwashing) [2,7].

However, the principles discussed in this paper can be applied to the removal of *Cryptosporidium*, provided appropriate values for the filter removal efficiency are used. For example, we can assess whether the widely used recommendation [6,10] to close the pool to enable six turnover cycles following an AFR is reasonable (assuming an input of 10^8 oocysts). If a filter efficiency for *Cryptosporidium* oocysts of 0.9 is assumed, as for example by PWTAG [10]), then Equation (10) predicts that after six water turnovers the concentration remaining would amount to 9000 m^{-3} in a 50 m^3 pool, and 900 m^{-3} in a 500 m^3 pool. Assuming that the average ingestion of pool water is 37 mL [7], the average ingestion of oocysts from pool water after 6 h of filtration would therefore be 0.3 and 0.03 oocysts in a 50 and 500 m^3 pool, respectively. This is below the reported infective dose for *Cryptosporidium* [2,7]. However, if the filter efficiency is 0.5 or 0.2 (e.g., a sand filter with inadequate coagulation [4,18]), then a similar arithmetic leads to the conclusion that the numbers of oocysts ingested on average following six water turnovers increases in the case of the 50 m^3 pool to 3.7 (E = 0.5) and 22.3 (E = 0.2) oocysts. This is within the range of the reported infective dose for *Cryptosporidium* [2,7] and suggests that in these cases six turnover cycles might be insufficient. This also raises the question of how filtration efficiency can be evaluated in pools [7].

The above is a simplistic exercise, and there is urgent need for more refined Quantitative Microbial Risk Assessment (QMRA) for *Cryptosporidium*. For example, the filtration modelling provides a sufficiently simple approach that can be used to incorporate filtration removal into the QMRA modelling, as recently developed by Falk et al. [22], but this is beyond the scope of this paper.

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