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The Source and Means of Spread of the Avian Influenza Virus in the Lower Fraser Valley of British Columbia During an Outbreak in the Winter of 2004

An Interim Report

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1. Executive Summary

During the winter and spring of 2004, an avian influenza outbreak occurred in the Lower Fraser Valley of British Columbia. Over a three month period, approximately 13.6 million commercial poultry and 18 thousand backyard birds were destroyed as part of disease control measures implemented by the Canadian Food Inspection Agency (CFIA). Most of the commercial poultry were broilers from uninfected flocks and went directly to slaughter at maturity to be used for human consumption. While 42 commercial operations were found infected, constituting 5% of the operations in the Valley, a wider cull of 410 non infected poultry flocks took place which affected more than half of the producers in the region. The economic impact of this outbreak on the livelihoods of British Columbia (BC) poultry producers and the associated support industries was severe and recovery is expected to be protracted. Fortunately, the avian influenza subtype causing disease in the region had minimal effects on persons living in the area or those working directly with infected poultry. Only two confirmed cases of mild conjunctivitis were reported in disease control workers directly in contact with infected birds over the outbreak time span.

The outbreak of high pathogenicity avian influenza (H7N3) is thought to be caused by a mutation from a low pathogenicity avian influenza strain. The low pathogenicity virus circulated in one barn of an Abbotsford broiler breeder flock and became highly pathogenic as it moved to an adjacent flock on the same premises. Once a flock becomes infected with a high pathogenicity strain, sufficient virus is shed into the localized environment to make biocontainment difficult. The disease spread quickly in the Abbotsford area for two main reasons. Many flocks were not protected by acceptable on- farm biosecurity practices and with regular traffic on farms, transfer of dust from contaminated premises was made possible leading to disease transmission to these flocks. A second reason for the rapid spread of disease from flock to flock is thought to be through aerosolized dust emitted from poultry barns. The opportunity for air exchange between barns was highest in the poultry farm dense areas of the Lower Fraser Valley where barns were within several hundred metres of one another. The Agency, along with other stakeholders, may have contributed passively to the spread of avian influenza in the Lower Fraser Valley due to the time between detection of disease and the destruction and disposal of infected birds. The processes of disease detection, flock euthanasia and carcass disposal required significant human and material resource acquisition, inter department dialogue and problem solving, logistical planning, and communications in order to be implemented on the short notice demanded by the crisis.

The biggest vulnerabilities of the British Columbia poultry industry which contributed to this outbreak were the low level of biosecurity practised by some poultry sectors coupled with the very high density of poultry farms in the region. To address these weaknesses, all BC poultry sectors should develop and encourage their producers to implement comprehensive biosecurity programs. These programs should be established according to principles practised by Canadian poultry breeders of high security primary and multiplier flocks. The current evidence for the potential for windborne dispersal of avian influenza suggests that development of an air inlet filtration system for barns would be prudent in the event of a second outbreak. Municipal bylaws for land use could be reviewed in light of the outbreak with a view to restricting permits for new commercial operations when deemed too close to existing farms.

2. Introduction

During the outbreak of high pathogenicity avian influenza (H7N3) in the Lower Fraser Valley of British Columbia, the British Columbia Emergency Operations Centre (BCEOC) established an Epidemiology team. A key role of this team was to investigate the sources of the virus on the Matsqui Prairie and the multiple, potential modes of disease transmission of the virus from farm to farm. This was accomplished through the contributions of many professionals serving on the team and from other federal and provincial departments. We received more than fifteen fully referenced reports on key subjects of concern, each carefully written during the outbreak. These reports were used to steer a course through the crisis by providing answers to immediate questions. As well, they provided the knowledge and information required to ensure we were gathering the right data for the final epidemiological analysis of the avian influenza outbreak events.

The purpose of this report is to provide information to poultry producers on the current state of knowledge and the status of the analyses of the origin and spread of the avian influenza virus in the Lower Fraser Valley during the winter and spring of 2004. It represents a synthesis by the BCEOC Epidemiology Team Leader, Dr. Christine Power, of the information provided by the many investigators and consultants contributing to the outbreak investigation. In addition, its purpose is to provide interim biosecurity recommendations to the poultry industry in British Columbia based on the information available at this time. Section 6.0 contains the list of contributors and papers forming the foundation of this report.

3. Source of the Virus on the Matsqui Prairie

Avian influenza is a contagious viral infection caused by the influenza virus Type "A", which can affect most species of food producing poultry (chickens, turkeys, quail, guinea fowl, ostriches, emus, ducks, geese and pheasants), as well as pet birds and wild birds. Avian influenza viruses can be classified as low pathogenicity (LPAI) or high pathogenicity (HPAI) according to the severity of the illness caused in birds. LPAI strains are much more common than HPAI strains in bird populations and typically cause less severe and on occasion no clinical signs in infected birds. However, some LPAI strains are capable of mutating into HPAI strains which leads to a severe form of the disease with high mortality. There are many influenza subtypes, two of which include H5 and H7. Historically, only the H5 and H7 subtypes are known to have become highly pathogenic in avian species.

On February 9, 2004, on the north east corner of the Matsqui Prairie, British Columbia, a broiler breeder producer noticed a mild drop in egg production and feed consumption and a slight increase in mortality in a 52 week old flock of 9200 birds. The farm's veterinarian and the feed company representative investigated the case and samples were submitted to the British Columbia Ministry of Agriculture, Food and Fisheries (BCMAFF) diagnostic laboratory for routine post-mortem. Pathogenic findings included unusually firm lungs and inflamed tracheas. The clinical illness appeared to resolve over subsequent days.

A diagnosis of avian influenza was made by BCMAFF's poultry pathologist on February 16, 2004. Within a few days, the subtype of the virus was identified as H7N3 by the National Centre for Foreign Animal Disease (NCFAD). This disease event, though mild in impact on the flock, is believed to be the origin or starting point of the HPAI outbreak. Throughout this report we refer to this farm as the "index premises".

By February 17, 2004 an adjacent barn on the index premises containing a younger flock of 9030 birds (24 weeks of age) began to show an alarming rise in mortality such that by the 19th, 1500 birds were found dead on that day alone. Laboratory testing conducted by the NCFAD in the weeks ahead revealed a different strain of the same virus found in the first barn. While the strain isolated in both barns was identical with respect to the subtype (H7N3), the pathogenicity of the viruses were markedly different. It was presumed at the time and confirmed later by testing that the second flock carried a high pathogenicity avian influenza virus (HPAI) that was a mutation of the low pathogenicity avian influenza virus (LPAI) found in the first flock.

In the first section of this report, the investigation into the source of the avian influenza virus during the outbreak focuses on the origin of the LPAI strain found in the first flock on the index premises. The HPAI viral strain is the focus of the second part of this report dealing with the means of spread of avian influenza in the Lower Fraser Valley.

3.1 Waterfowl Versus Domestic Poultry as the Source

Waterfowl are well established primary reservoirs for a wide variety of strains of avian influenza and in the past have been implicated in the spread of influenza to commercial poultry. In waterfowl, infection with avian influenza is unapparent with primary intestinal replication and subsequent shedding of virus in faeces. Occasionally the same bird has been found to be infected with multiple subtypes.

Avian influenza has been recovered from 20 of the 42 species of indigenous North American ducks, geese and swans. All fifteen hemaglutinin (H) subtypes have been isolated from wild waterfowl worldwide but the predominant H subtypes in North American ducks include H3, H4 and H6 with H5 and H7 being poorly represented (0.4% and 0.7% of over 3100 isolates respectively). The continued recovery of H3, H4 and H6 subtypes, in significant proportion and over 30 years of accumulated data, suggests that these subtypes are host-adapted to waterfowl. Host-adaptation implies that a waterfowl strain does not commonly transmit to domestic fowl. Although genetically stable in its natural host, once an AI virus crosses the species barrier there is an accelerated mutation rate that gives rise to genetic diversity and the possible emergence of pathogenic strains. The pathogenic strain which emerged in the second flock on the index premises is an example of such a mutation.

Given the Matsqui Prairie lies on a migration route and in the month of February waterfowl and other wild birds are a common sight in ditches and fields, the source of the virus was thought to be most likely derived from migratory or resident waterfowl carrying the virus and shedding it in their faeces to contaminate the environment. While very few surveys have been conducted in the area, information available suggests the H7 strain is rare in waterfowl along the west coast of North America and that peak influenza shedding is in juveniles in the fall of the year. Nevertheless, the documentation of the direct transmission of avian influenza from waterfowl to turkeys in past outbreaks in the US and Canada suggests serious consideration be given to migratory birds as the source of virus.

Secondly, since host adaptation is expected to reduce the infectiousness of the viral strain to domestic birds, another possibility is that the LPAI virus isolated on the first premises did not come directly from migrating waterfowl. Waterfowl-derived virus could act as a donor of the original hemagglutinin (H7) gene with subsequent poultry adaptation occurring in small backyard flocks that commingle with wild waterfowl or their habitat. It is possible for a virus strain of waterfowl origin to adapt to domestic poultry over time if waterfowl and backyard chickens have access to the same environment. With this kind of contact, a chicken- adapted strain could develop and then circulate in backyard flocks or live bird markets quite undetected until introduced into a commercial poultry flock.

Thirdly, domestic poultry could also have been the source of the LPAI virus on the index premises. The likelihood of this event may be very low but consideration of all avenues is required. While a small proportion of day old chicks and hatching eggs are imported to British Columbia, the vast majority are produced within the Lower Fraser Valley. The prevalence of LPAI in poultry flocks in BC prior to the outbreak is not known. Transfer of virus from a domestic poultry source to a broiler breeder operation could have (in theory) occurred through contaminated egg trays.

In BC, on these farms, eggs are delivered from the laying house via conveyor belt or by hand to a common room where settable eggs are put on flats, either on racks or in boxes. Then eggs are stored in a cooler until picked up by the hatchery. Eggs are picked up on the farm by hatchery trucks. Floor eggs may be included in the pick up. This is especially true in BC where producers are compensated based on the number of eggs set rather than the number they hatch. Racks and flats may be used on multiple farms. Egg racks and flats are reused and not necessarily sent back to the same farm. Although power sprayed and disinfectant applied, broken egg contents cling to racks and could provide a source of virus when racks are delivered to a farm. This was believed to be a route of transmission among commercial layer flocks in California during a recent incursion of Newcastle's disease. Their response was to develop a protocol whereby racks were color coded and returned to the same farm. The protocol also called for single use paper flats so that no flats would return to any farm.

It is important to point out that the Abbotsford outbreak data did not single out any hatcheries for increased association with HPAI infection on broiler breeder operations, which is to say that hatcheries were not implicated in the spread of the high pathogenicity form of the virus.

Another means of potentially moving LPAI from one broiler breeder flock to another is through the practice of "spiking" which involves transferring roosters from one premises to another during the laying period. This is a common practice among BC broiler breeders operators. Since LPAI is not always noticeable in a flock, there is a danger of inadvertently infecting a recipient flock in this way. Still another concern revolves around the reported practice of the illicit sale of ungraded eggs by some broiler breeders and commercial table egg producers. The movement of buyers from farm to farm in conducting egg pickup can lead to biosecurity breaches and inadvertent disease transmission to a flock.

3.2 The Genetic Profile of the LPAI Virus

The genetic make-up of the LPAI virus isolated on the index premises can help to answer the question of whether it most likely came from waterfowl or from domestic poultry. So far, two major genes have been sequenced by provincial and federal laboratories. What is known now is that the gene encoding the H protein of the virus has a nucleic acid sequence very similar to those of a virus strain found in domestic poultry from Eastern North America. On the other hand the gene encoding the matrix (M) protein of the virus has a sequence much like that from a virus strain found in waterfowl in the Southern United States. As mentioned earlier, different influenza virus strains can exchange their genetic material readily when they co-infect the same host (bird). While the information to date provides no definitive answer, the complete sequence of the remaining viral genes of the LPAI isolate will soon be available and will enable a comparison with the genetic profile of strains from around the world. This work should help to establish the predominance of wild versus domestic components of the viral genome. In this way we hope to obtain a clearer picture of where the original virus came from and whether it was of waterfowl or domestic origin. This information is expected to be available in the fall of 2005.

4. Considerations in the Spread of the Avian Influenza Virus from an Infected Premises to a Susceptible Flock

An adjacent barn on the index premises containing a younger flock of 9030 birds (24 weeks of age) began to show an alarming rise in mortality on February 17, 2004 such that by the 19th, 1500 birds were found dead on that day alone. Infection of this second flock on the index premises with the mutated strain of the avian influenza virus constituted the beginning of the HPAI outbreak event. Three weeks later a second premises 1.6 km away showed signs of infection, then one week later three more premises (2-3 km) south and west became infected. Two weeks later 11 additional commercial premises were identified as infected and in this way the epidemic began slowly and picked up speed as more flocks became infected.

By the time the outbreak was brought under control, infected farms appeared in three clusters, each of which had a diameter of 5-6 km. In a few cases outlying farms were positive on the screening test but flocks did not show clinical signs or appear to contribute to local spread. The flocks themselves, once infected are known to shed enough live virus into their localized environments to be considered as virus factories.

From early on, the spread of the HPAI virus in the Abbotsford area was investigated from many points of view in order to establish the most probable means of disease spread during the outbreak event. The potential roles of wild birds, ground water, surface water, wind-borne particles, bio-security gaps (inter- farm movement of people, equipment), hatcheries, feed and feed mills, farm service personnel and CFIA staff in their eradication efforts were evaluated by the Epidemiology team during the course of the outbreak. This next section, under these key headings, provides the salient facts and observations for each mode of transmission along with preliminary biosecurity recommendations for the poultry industry.

4.1 Transmission Through Poultry Manure/Litter (Sawdust)

4.1.1 Background

The avian influenza virus survives for many weeks in wet poultry manure at cool spring temperatures (4 °C), and for up to ten days at 25 °C. The virus dies within a day or two in very dry faeces. The concentration of virus shed in the faeces of infected poultry is very high. A gram of infected faeces can contain as many as ten billion infectious virus particles. Transmission of contaminated manure from an infected premises to a separate susceptible flock can an occur through the movement of people, equipment and vehicles. Barn to barn movement constitutes the highest risk activity for transfer, while deposition of contaminated manure in the vicinity of a susceptible flock is categorized as of somewhat lesser risk. It is thought that a small amount of contaminated dust adhering to boots, clothing or equipment is sufficient to transmit the virus from an infected barn to a susceptible flock.

A 2001 survey of biosecurity practices of poultry producers in the Lower Fraser Valley by BCMAFF revealed serious omissions which would leave producers vulnerable to disease incursions. For example, more than three quarters of commercial broiler and table egg operators indicated they do not provide disinfection footbaths or require a change of clothes/coveralls by employees on entering their barns.

During the outbreak, the CFIA investigation of each infected premises included a questionnaire of farm management practices and environmental observations very similar to that employed by BCMAFF in 2001. The time lines for the on-farm events were plotted and reviewed for common visits by feed companies, hatcheries, other service providers and guests. The information derived from the first five infected premises of the outbreak did not point to a common service provider (or visitor) as a means for spread of the virus. However, this does not rule out viral spread resulting from the movements of multiple parties during that time period. It is important to note that there was normally a great deal of traffic on and off farms in the Abbotsford area and if proper biosecurity practices were not used on farms, the potential to spread disease was very real.

4.1.2 Biosecurity Recommendations for the Poultry Industry

Considering the large number of poultry service providers coming and going on poultry farms during a normal production cycle coupled with the close proximity of poultry producers in the Lower Fraser Valley, comprehensive biosecurity programs for both poultry producers and service providers are strongly recommended. Canadian breeders of primary and multiplier flocks for the poultry sectors have long established standards of biosecurity which have evolved over decades of trial and error. These companies have the knowledge, expertise and experience to provide solid direction to the BC poultry producers as they develop programs of their own.

Biosecurity programs must address multiple potential avenues of disease (virus) entry on the farm. For example, a fifteen point program developed by Cuddy Farms contains the following components:

-Conditions of employee hiring
-Control and sequence of vehicle movement
-Control and sequence of employee movement
-Control and screening of visitors
-Location of farms
-Control of bird placement
-Biosecurity barriers
-Wild bird control
-Rodent control
-Insect control
-Control and monitoring of feed production
-Minimum down time. Monitoring of clean-out and disinfection
-Rapid diagnostics and high frequency of disease monitoring, disinfectant efficacy and concentration testing
-Biosecurity audits
-Employee education

In British Columbia, the BC Poultry Association has developed a Poultry Industry Biosecurity Manual which provides a producer self-assessment guide, minimum biosecurity standards for commercial poultry farms and a strategy for developing an on-farm biosecurity program.

4.2 Transmission Through Water

4.2.1 Background

The persistence of avian influenza virus in water under natural field conditions is not known. However, under experimental conditions the virus survives, to varying degrees, for months at temperatures between 4 °C and 28 °C. Considerable variation exists between viral strains with respect to changes in temperature, pH and salinity. Perpetuation of avian influenza virus in wild waterfowl is assumed to occur via contaminated water. Since virus replication is primarily within the digestive tract in waterfowl, transmission of virus is through the faecal-oral route.

While clear associations between waterfowl and free range and confined poultry and the transmission of disease have been established in Minnesota outbreaks in turkeys in the early ‘80s, the role of contaminated water from an infected premises causing transmission to another premises is not recorded in the literature. Nevertheless, the likelihood of surface water and ground water transmission on the Matsqui prairie were investigated with assistance from BCMAFF ’s Resource Management Branch in March 2004.

The concern was that run-off from infected premises may have entered either surface water or ground water. Since no manure was spread onto the fields after the discovery of HPAI, contaminated run-off would have to have occurred during times of depopulation, removal or composting of birds. Rainfall records from the periods of depopulation of the first two infected premises were analysed in the light of infections on three subsequent premises. The rationale was that contaminated surface water would have to travel in ditches downstream from one premises to another and then be introduced mechanically into the susceptible barn by a producer’s dirty boots or a wet farm dog fresh from taking a dip in a ditch. Using surface water drainage maps produced by Resource Management Branch showing the creeks and ditches and the direction of water flow along with farm activity information provided by the producers, it was concluded that transmission by surface water from one farm to another was possible but the risk was likely to be low. As well, several dozen water samples taken from ditches and sloughs scattered across the Matsqui Prairie in early April failed to demonstrate avian influenza virus through laboratory testing.

The concern that ground water could be a source of viral transmission was discussed with authorities from BC Water Land and Air Protection and the Drinking Water Program of the Fraser Health Authority. Both reported that while no measurements of ground water flow were being done in the area, given the flat topography and sand and fine gravel sediments in the area, expected groundwater flow would be less than one metre per day. Questionnaires administered to the owner/manager of each infected premises indicate that only Premises 1 and 2 used wells (sand point), while Premises 3-5 obtained their water from a municipal water system. Research on another type of virus (enteroviruses) indicate that they may traverse 60-70 meters in a vertical direction and 500 meters horizontally. Given the distances between the farms, slow ground water flows and only two premises using well systems, it was considered highly unlikely that contaminated ground water had spread the HPAI virus from one commercial operation to another.

However, it is not inconceivable that contaminated surface water from a field near the index premises drained downward into the farm well bed some 18 feet below the ground surface and through this means found its way into the water supply to the barn. In this way, the LPAI strain may have entered the index flock as an original point of entry in February.

4.2.2 Biosecurity Recommendations to the Poultry Industry

As part of the development of biosecurity programs by the Canadian poultry industries, continued consultation with local expertise in the BC government to appraise the risk of contamination of well beds from highly localized surface water seepage from fields is suggested. In addition, the merits of installing water purifiers in barns should be assessed.

4.3 Transmission Through Feeds

4.3.1 Background

Consideration of virus contaminated feed as a point source to the epidemic was evaluated through an investigation of two feed companies supplying feed to the affected producers. The types and sources of feed ingredients were reviewed with the feed mill operators against the chain of production, storage, milling and transportation to the farm. Since these feed mills were Hazard Analysis at Critical Control Points (HACCP) certified, the review of the process with respect to areas where bird droppings could have been introduced into the feeds was straight forward. Only a few areas were highlighted as unattended means of virus introduction and survival through the complex process of feed manufacture.

Feed company staff pointed out that protection of grains from wild birds during transit and storage is routine, yet as a field crop, grains are exposed to wild birds. Since these grains are purchased from all over North America, it is possible that grains could be contaminated in the field and then moved across large geographical distances. While broiler rations undergo a final heat treatment step in the process of pelletizing, broiler breeder rations are prepared as a mash feed which does not undergo heat processing. While faecal contamination of grains is not likely to ever cause an multi-farm outbreak, it is possible that the index farm (a broiler breeder operation) was infected through a tiny amount of contaminated grain in the feed. As more information becomes available as to the genetic makeup of the LPAI virus, it may be possible to find a connection with viral samples collected from surveys of waterfowl migration routes across North America.

Another area of concern revealed through the investigation was the practice of back hauling feed from farms to the mill and subsequent redistribution. This occurs when the producer reaches the end of the production cycle of the flock and there is a significant amount of feed left over. As courtesy to the producer, the mills back haul and recycle the feed. Contamination of stored feed at the producer level could be transmitted to other flocks through this process. Having stated this, there was no association between any particular feed company and the pattern of disease spread among the first five farms in the outbreak.

4.3.2 Biosecurity Recommendations to the Poultry Industry

A risk assessment could be done to assess the plausibility and likelihood of transmission of virus through contaminated grain crops. If a significant risk is determined, consideration of mitigating measures (ex heat treatment/irradiation) could follow.

Secondly, a review of the practice of back hauling feeds should be undertaken to ascertain the appropriate measures required to reduce the risk of recycling potentially contaminated feed.

4.4 Transmission through Aerosol/Airborne Dust Dispersion

4.4.1 Background

In the early stages of the outbreak, the infected premises were found to be fairly close together (within 2-3 km of one another) and down wind from the prevailing NE winds on the Matsqui Prairie at that time of year. While the scientific literature does not define wind movement as a principle source of avian influenza virus transfer, discussions with scientific leaders in the field of avian influenza from Italy, the Netherlands and United Kingdom in April 2004 revealed markedly divergent opinions from “highly sceptical” to “a considerable factor to deal with”. Clearly revealed was the absence of any testing to support or refute a windborne theory of transmission during recent outbreaks in Italy and the Netherlands.

Poultry barn emissions in the Lower Fraser Valley have long been a focus of interest by Air Quality Meteorologists in the BC Ministry of Water, Land and Air Protection due to concerns over their contribution to summertime air pollution. A consultation with Ministry staff in April proved very informative as they were able to answer many of our questions concerning the amount of dust emitted from poultry barns and the potential for windborne dispersion. Briefly, an aerosol consists of solid or liquid particles suspended in air. Dust, smoke and fog are examples of aerosols. Dust emissions can be broken down into two basic fractions: visible particles larger than 10 microns in diameter which settle out by gravity and invisible particles less that 10 microns which are light enough to be suspended in air for long periods.

In the Lower Fraser Valley, many poultry farms use sawdust, as the readily available by-product of the lumber industry, as litter for their flocks. Poultry feed, faecal material from birds along with feathers and dander also contribute to the dust emissions from barns.

Contained in this report were the results of a study conducted by the Sustainable Poultry Farming Group in which aerosol emissions from an Aldergrove, BC broiler operation were measured over a full growth cycle. While anyone observing dust emissions from a barn with dimensions of 40 x 400 feet with 20,000 birds bedded on sawdust would agree that they are substantial, of particular interest is the invisible portion which can be suspended in air and transported by wind. This fraction constitutes a particle size of less than 10 microns in diameter and is invisible to the naked eye. Emissions of this size range were measured from a 24 inch fan over 7 weeks revealing output of 25-40 g/m^3 per 24 hour period. To illustrate the magnitude, this represents a million fold elevated concentration of aerosolized dust near a poultry barn fan as compared to outdoor air in a semi-rural area such as Aldergrove. Of all measured total particulate matter (visible and invisible) emitted, 40% was found in the invisible size fraction of less that 10 microns in diameter. This indicates that a sizable portion of dust emissions from poultry barns have the potential to remain suspended in the air for up to several days. Given the spring time winds in the Fraser Valley often range between 5-10 km/hr, poultry barn dust could possibly be found tens of kilometers from their source.

Little is known about the survival of avian influenza viruses in dust particles due to limited experimental work conducted to date. Available published studies indicate that survival is best in dry air where the relative humidity is less than 50%-70%. It has been suggested that other factors capable of significantly decreasing the survival of the avian influenza virus in aerosols include ultra violet radiation, ozone reaction products, air ions and pollutants while high air salinity found in coastal areas may provide a protective effect on virus survival.

In early April, the Agency, as part of its epidemiological investigation, undertook a study to examine airborne spread of virus near infected barns. This study was conducted collaboratively with Defence Research and Development Canada-Suffield (DRDC) of the Department of National Defence, experts in sampling and detection of biological agents in aerosols and Health Canada, providing the laboratory testing expertise.

The goal of the study was to evaluate if avian influenza virus was being spread into surrounding areas on dust particles emitted from barns containing infected birds. Agency epidemiologists hypothesized that airborne transmission of the virus might be contributing to the rapid and extended spread of the outbreak.
Air sampling near infected barns: The study assessed air samples collected adjacent to three infected premises using low volume air samplers. On each farm, air samples were collected every fifteen minutes for a 24 hour period both upwind and down wind from the ventilation fans of the barns. Of a total of 240 air samples collected from fixed locations, all were determined to be negative for the avian influenza virus.

Air sampling inside an infected barn: Live virus- virus capable of causing disease- was detected in two of two samples collected by high volume air sampling inside an infected barn. A quantitative estimate of viral load per cubic metre of air was determined and found to be very high.

Air sampling in the surrounding area of infected barns: Nine air samples were collected within one kilometre of known infected premises using high volume air sampling. Very low levels of virus were detected in one of these samples some 800 metres from an infected barn. Testing was unable to determine if this remote sample of virus was alive or dead.

Although this study confirmed that avian influenza virus was circulating in the air outside barns during the outbreak, it remained unclear if the virus was alive and therefore potentially infectious. A complete report of this work will become available in the months ahead from the DRDC.

Evidence of what appeared to be windborne transmission in the third week of March, as the disease spread to the fourth and fifth premises, reinforced the Agency's resolve to minimize any potential airborne transmission. The Agency's on-farm activities were directed by the CFIA's HPAI disease control strategy such that once an infected flock was identified, efforts were made to destroy birds as quickly as possible to limit the amount of virus produced. During disposal activities, dead birds were collected indoors and sealed in boxes before being transported off the farm. Barn doors were kept closed as much as possible during the disposal process to prevent air currents from spreading virus. In-barn composting of birds and litter was introduced by Agency research staff early in the outbreak and conducted thereafter by Agency operational staff. Wherever possible composting took precedence over removal and incineration of birds.

At this point in the outbreak, the definition of infected flocks was expanded to include flocks that showed clinical signs or were positive on the screening test. Until this point, a confirmed diagnosis of avian influenza subtype H7 was required, involving a screening test (offering same day results) followed by an H7 confirmation test (requiring 1-5 additional days). Changing the case definition to include flocks which were positive to the screening test without the benefit of H7 subtype confirmation results in hand, permitted more rapid disease response actions. This modification was based on a high probability of correlation between the two tests. In other words, while the screening test would identify other subtypes of avian influenza if circulating in a flock, the likelihood of this occurring was relatively small. In order to clarify the disease status of the screening test-positive flocks which failed to demonstrate the H7 subtype, some 14 commercial and 9 backyard flocks, a retrospective analysis is planned.

4.4.2 Biosecurity Recommendations to the Poultry Industry

The current knowledge of the potential for wind dispersion of avian influenza in the Abbotsford area suggests that installation of a barn inlet filtration system would be prudent in the event a second outbreak. Ventilation engineers in the agricultural sector would be a good source of expertise and creativity for the design of an inlet filtration system. Realistically this may constitute a significant expenditure to poultry producers given that the air inlets of poultry barns usually run the entire length of the building. However, the cost-benefit ratio may make such a system an attractive outbreak protection option for producers.

A second suggestion arising from the outbreak experience is for the poultry industry to develop an air cleaning system to disinfect or remove infected material from exhausted air as it leaves an infected barn. This system would be used for known infected premises to allow the fans to run until the work of flock euthanasia, disposal and composting could be completed. Fans must run continuously for days while these activities are underway for humane reasons for the birds and for ventilation reasons for crews working in the barn during cleanup. The risk of airborne transmission could be greatly reduced with a practical means to disinfect the exhausted air.

4.5 Transmission Through CFIA Activities

4.5.1 Visits to farms by CFIA staff

Since the onset of the outbreak, the CFIA was warning of the dangers of industry service personnel visits on poultry farms as a potential means of transferring virus to susceptible premises. During the first month of the outbreak the CFIA dispatched crews to infected and non infected premises on a daily basis for collection of samples for disease detection, for removal of birds from contaminated flocks and related disposal activities. Strict biosecurity measures were employed by CFIA personnel entering poultry premises and barns. Training of all field staff in biosecurity practices was required. Single use coveralls, masks, eye protection and foot wear were mandatory. A biosecurity quarantine period was established such that no visits to poultry farms were permitted for 24 hours following a visit to a non infected farm and no visits to poultry farms were permitted for 72 hours following a visit to an infected farm.

In March, some producers expressed concern that the CFIA staff were infecting their flocks. To address these concerns, an objective analysis of the CFIA visits relative to subsequent flock infections was undertaken. At the time of some visits by the CFIA, a flock was believed to be non infected, but if infection was detected within 10 days of that visit, the flock may have been shedding virus at the time of that visit. In this type of situation the CFIA workers would have followed a 24 hour biosecurity quarantine period rather than the 72 hour period required for visits to infected premises. Using the dispatch records a review of the inspectors movements was carried out to identify this higher risk event for all workers. An assessment of the rate of infection observed in flocks following a high risk visit as compared to the rate of infection of flocks following a non high risk visit showed no significant difference in the rates of infection in both commercial and backyard flocks. Therefore no association could be found between the on farm activities of the CFIA and an increased spread of disease by their visits.

4.5.2 Dispersion of feathers and dust during disposal activities on the first two infected premises

In the early weeks of the outbreak, the CFIA tried out several procedures of euthanasia and carcass disposal on the first two infected premises to establish a humane depopulation method and a safe way to dispose of thousands of infected carcasses.

Barns on the index premises underwent bird removal by hand transfer to a conveyor belt which transported the carcasses to an open door at one end of the barn. The carcasses were loaded into a grinder which in turn was emptied into a dump truck for localised transportation for composting. This process of moving carcasses outside the barn followed by grinding for composting was recognized for the potential it held to transmit infected feathers and dust into the wind and surrounding environment. Carcass disposal activities were confined within barns afterwards.

On Premises 2, the CFIA tried out an established euthanasia method provided by a BC poultry industry which, because of the size of the equipment, required that birds be transported outdoors for the process. This lead to a significant amount of feather dispersion on the wind and in the surrounding environment. This method was never repeated and it, too, was held up by government and industry as an unfortunate learning experience.

Did these events contribute to the spread of virus to other premises? This question was investigated through a qualitative risk assessment which evaluated the likelihood of transmission during the known hours of high risk activity on these farms, considering the wind direction and speed at those times, and the timing of infection on Premises 2, 3, 4 and 5. Meteorological data were obtained from the Abbotsford airport hourly observations.

Recall from Section 4.41, that visible dust (including feathers) tends to settle to the ground just tens of metres from their source, while the invisible component of dust (less than 10 microns) can be carried on the wind long distances and have the have the potential to remain suspended in the air for up to several days. It is the invisible dust, once aerosolized, that is thought to carry the highest risk to neighbouring farms.

The assessment showed that wind directions and speed during high risk activities on Premises 1 provided a moderate risk rating for windborne dispersion to Premises 2, a low risk rating for Premises 3 and a negligible risk rating for Premises 4 and 5. The risk of transmission from Premises 2 were estimated as negligible for Premises 3 and low for Premises 4 and 5.

These events may have contributed to the spread of disease. However, in addition to the dust dissemination associated with these events, the volume of exhausted dust from these infected barns may ultimately have been more influential in transmission. The continuous operation of fans required to ventilate birds and disposal crews over many days and nights leads to significantly greater emissions than what would be expected by the outdoor activities alone. Recall also, that little is known about the survival of virus in aerosolised dust. Ultraviolet radiation from the sun during daylight hours is expected to kill virus quite effectively. While further clarification is anticipated through ongoing analysis of the outbreak data, basic research is also needed into the transmission dynamics of avian influenza to establish definitive answers to the mechanisms of viral spread.

4.5.3 Dispersion through transportation of infected poultry by trucks

A driver of a car travelling behind a convoy of trucks carrying poultry carcasses related that fluid emanated from the surfaces of a box trailer and that it sprayed onto the surface of his vehicle. He reported the event to the CFIA along with his concern that he may have been exposed to fluids from infected birds. This liquid most likely was disinfectant used to spray the outside of the box trailers prior to departure from an infected premises. However, there were known cases where poultry fluids leaked from the back of refrigerated box trailers en route to disposal sites.

Poultry carcasses were routinely protected by a triple sanitary barrier consisting of two layers of heavy duty plastic liners contained within an industrial strength cardboard box (1 m^3 volume). Boxes of carcasses on wooden palettes were placed in refrigerated box trailers. The box liners, consisting of a double layer of plastic, were designed for carrying boneless beef. Whole poultry carcasses have sharp beaks and claws which can cause perforations in the liners with subsequent leakage into the boxes and onto trailer floors. As a matter of routine, floor drains were plugged and 150-200 kilograms of clay litter was placed at the back of the trailer unit. This was done to absorb any potential fluid leakage moving from the front of the trailer unit to the back as occurs when a truck accelerates or climbs a hill. This level of containment was considered reliable in ensuring fluid leakage was prevented or minimized. However, there were occasions where fluid was observed dripping from the back of loaded box trailers on the highway by CFIA staff as they followed behind. These events were generally associated with transportation of birds from premises where collection delays and heat had caused decomposition and liquefaction of dead birds prior to packing and loading.

The likelihood of transmitting contaminated fluids discharged onto a road surface to the inside of a poultry barn is thought to be low. It would require a vehicle to drive over the fluid on the highway, then onto a farm, depositing fluid from the tires onto the farm driveway. From there a person on the farm would have to contaminate their shoes on the driveway, for example, and then track virus into a barn. If all the conditions were right, it could possibly happen. The actual contribution of trailer leakage to the outbreak is unknown but will be considered in future analysis.

While difficult to prevent leakage in every shipment given the prescribed packing materials of the day, steps should be taken by the CFIA to identify materials and methods which would eliminate fluid escape from trailers altogether. Also, the disposal of birds and litter through on-farm composting was used effectively during the outbreak. It offers enhanced bio-containment of virus on the farm and wherever possible should be used instead of removing birds for disposal at off-farm locations.

4.5.4 Management of leakage from parked trailers on a Richmond industrial site

On March 15, 2004, infected birds from Premises 2 were boxed and hauled in refrigerated trailers to an industrial site in Richmond, BC some 70 kilometres south west of Abbotsford. The site was located south of the Vancouver airport. On March 16, 2004 two refrigerated trailer units were found to be leaking organic fluid (a strong red colour) onto the ground. This fluid was found on the asphalt and gravel surfaces surrounding the trailers, and had entered a drainage ditch which, itself, drained into a nearby stream some 75 metres away. This stream emptied into the Fraser River approximately one quarter of a kilometre away and the Fraser River emptied into the ocean about one kilometre from that point. An Environment Canada engineer was immediately called to assess the leakage situation. During the investigating of the site, leakage volumes were assessed, corrective actions were prescribed for immediate handling of fluid accumulations on the ground and recommendations were provided for fluid containment and remedial management of the drainage ditch. The CFIA implemented these recommendations as directed.

Briefly, the process consisted of applying absorbent clay particulate material (kitty litter) and disinfectant to the contaminated ground surface, waiting a day, followed by physical removal and bio-secure disposal of the material. The two offending trailers were chilled down to freezing temperatures over several days, packed to prevent further leakage and hauled to Princeton to dispose of their cargo on the evening of Saturday, March 20, 2004. At this time, a final application of dilute chlorine bleach was applied to the entire parking site.

The organic fluid which drained from the parking area into a nearby drainage ditch was found to have settled to the bottom of the ditch in a congealed state. Since the spill was deemed stable "as is", disruption of the site was contraindicated until a remediation service could be contracted to block the ditch, remove the organic fluid and provide restoration. By April 7, 2004 such remedial action was completed at the site.

Overall, while the leakage was viewed as potentially serious, the management of the situation was prompt and appropriate. This helped the Agency identify precautions to be taken with future disposal and clean-up activities on a site that was remote from the poultry industry. It also helped develop future disposal procedures. While the offensive smell of the organic fluid caused concern among local Richmond residents, this event was not deemed to pose any significant risk to people, flocks owned by poultry producers nor to the water supply of the nearby Fraser River.

4.5.5 The role of time delays in the spread of disease

The Agency, along with other stakeholders, may have contributed passively to the spread of avian influenza in the Lower Fraser Valley due to the time between detection of disease and the destruction and disposal of infected birds. The processes of disease detection, flock euthanasia and carcass disposal required significant human and material resource acquisition, inter department dialogue and problem solving, logistical planning, and communications to be implemented on the short notice demanded by the crisis. On average, this process took seven days which is significantly more than the desired target of 24-48 hours. There are multiple reasons for this extended time frame which will be addressed by many of the recommendations contained in the Post-Incident Review of the CFIA's Response to the Avian Influenza Outbreak and the Report on the Canadian Poultry Industry Forum of October 27 and 28, 2004. The desirable rapid response time for disease management on farms requires a highly coordinated, emergency response program, exercised regularly by the Agency with all organizations partnering in the process. To be effective, everyone must be aware of their roles and responsibilities and act in a coordinated approach to control and eradicate the disease of concern.

4.6 Ranking of the Relative Importance of Possible Routes of Transmission

4.6.1 Preventing the introduction of avian influenza onto farms

When avian influenza is discovered on a poultry farm, the priority of investigative avenues are as follows:

Were poultry introduced into the flock recently? Seek a domestic source for the virus.

What is the biosecurity of the farm with respect to wild birds gaining access to the barn?

What is the biosecurity of the farm with respect to persons and objects gaining entry into the barn? Entrance to barns by persons and equipment constitute high risk activities for the flock. Producers, employees, bleeding and catching crews, veterinarians, equipment sharing events and visits inside the barn from outsiders all must be recognized as high risk persons/events.

What is the biosecurity of the farm with respect to moderate risk activities for the flock? Activities such as barn cleaning, egg pick up, repairman visits and media visits are considered of moderate risk because persons may enter the ante-room of the barn but don't usually gain entry to the flock.

What is the biosecurity of the farm with respect to low risk activities for the flock? Low risk activities include feed deliveries, feed representative visits, hatchery chick placements, manure/litter removal and sawdust/shavings delivery.

Once these avenues are reviewed and ruled out, the concerns can then turn to feed and water. The index premises was carefully managed with respect to most of the above biosecurity practices. This is an important fact to recognize. It is suggested that well water, feed source and hatchery crate recycling practices should not be overlooked as potential means of the original viral entry into the first flock on the index premises.

4.6.2 Preventing the spread of avian influenza from farm to farm during an outbreak

Once infected, flocks are known to shed enough live virus into their localized environments to be considered as virus factories. Therefore, during an outbreak of avian influenza , producers must ensure optimal biosecurity for all high, medium and low risk activities on their farm. This is essential for any producer who wants to avoid infection of their flock. Disease transmission is thought occur through breaches in flock biosecurity and through aerosol (dustborne) transmission from an infected barn to a susceptible one. The proportion of farms in this outbreak which acquired infection through each of these means is not yet known. Clarification is expected through further analysis (see Section 5.0). It would be fair to assume that barns within 500 metres of one another are at higher risk for aerosol transmission than those further apart. Poultry flock density in the Abbotsford area should be a very important consideration in the emergency preparedness planning for a future outbreak with respect to air inlet filtration and exhaust disinfection systems. In areas of high density, aerosol transmission should be anticipated. So overall, the key means of spread of the avian influenza virus during the outbreak is considered to be through high risk activities involving people and equipment and through dust emissions from infected poultry barns in close proximity.

5. Next Steps

This section provides descriptions of the key initiatives arising from the avian influenza outbreak. This is not an exhaustive list of planned projects.

5.1 Measuring avian influenza prevalence in domestic poultry and migratory waterfowl

Provincial government veterinary and laboratory services across the country conduct testing for avian influenza when indicated by clinical signs in a flock or by pathological findings of avian specimens. It was through such activity that the BCMAFF's poultry pathologist diagnosed the initial flock of avian influenza in Abbotsford. In spite of these activities, few studies have been conducted in recent decades assessing the prevalence of avian influenza in migrating waterfowl and domestic poultry in Canada. At this time, plans are under way by the CFIA to conduct a national serological survey in 2005 for avian influenza in the Canadian domestic poultry industries. Much of the sample collection is expected to be undertaken in federally registered slaughter plants across the country. Once completed, a clearer picture of the exposure of Canadian poultry to H5 and H7 avian influenza will be available.

Discussions between the Canadian Cooperative Wildlife Health Centre, Canadian Wildlife Service, Health Canada , the CFIA and others are under way at this time to establish the feasibility of conducting a national waterfowl survey for avian influenza in 2005. Since wild birds are the ultimate reservoir of the Influenza A viruses, identifying the strains carried by these birds is needed. Survey data derived from the Pacific flyway of BC may offer insight into the source of the virus on the Matsqui Prairie in February 2004.

5.2 Evaluating the role of poultry service providers in disease transmission

A study is underway to determine the relative influence of farm management practices, farm biosecurity, industry support sectors, social networks and environmental factors in the spread of disease in Abbotsford. Farm information collected during the outbreak is being used to ascertain the risk factors influencing the transmission of the virus. This work, carried out during the outbreak, uses the design of a case-control study which requires detailed information provided by producers whose poultry were infected with the virus and others who were spared the infection. The producers of 25 infected premises (case farms) were interviewed while 75 producers from uninfected farms (control farms) were questioned in the study.

In addition, predicted airborne dispersion effects from a study described below will then be introduced into the analysis of the case-control study to assess the relative impact of biosecurity breaches compared to airborne effects in transmission of disease in the Lower Fraser Valley. This analysis is underway in collaboration with the Faculty of Veterinary Medicine, University of Montreal. An interim account is expected in the fall of 2005 with final reporting expected in the winter of 2006.

5.3 Evaluating the role of windborne spread in disease transmission

The plausibility of airborne spread of virus in the Lower Fraser Valley is the subject of a second study. For eight weeks during the outbreak, a mobile weather station dispatched from Vancouver (Environment Canada), was placed on a farm on the Matsqui Prairie to capture local meteorological data for generating retrospective predictions of airborne movement during the outbreak period. In-barn viral concentrations measured in air (by DRDC) and the time sequence of infected premises events in the Lower Fraser Valley collected by the Agency will also be used in the analysis. An anticipated outcome of this work is clarification on the role of airborne dispersion in the early infections on the Matsqui Prairie (prior to March 19, 2004) and in the creation of the south and west clusters of infected premises that emerged in early to mid April. This study is being conducted in collaboration with Environment Canada's Environmental Emergency Response Division and the CFIA's Foreign Animal Disease group. A final report is expected in July 2005.

5.4 Assessment of the role of backyard flocks in the spread of avian influenza

During the outbreak some 553 backyard flocks were ordered destroyed as part the disease control measures exercised by the Agency. While more than 80% of these flocks contained less than thirty birds, a few flocks raised more than1000 birds. At the time of destruction, samples were taken from each flock for laboratory evaluation of disease status. This flock information will be used to conduct an assessment of the role of backyard flocks in the spread of the disease during the outbreak. Overall, this assessment will be used to appraise the Agency's current policy on backyard flock destruction and to direct policy renewal for future incidents. This work will be undertaken by the CFIA with a report anticipated in the fall of 2005.

5.5 Summary list of planned analyses, surveys and studies

An aerosol sampling trial of avian influenza in the British Columbia Fraser Valley	Final report expected in February 2005.
A genetic sequencing study of the AI virus to clarify its most likely source	Preliminary results expected in fall 2005
Risk factors for spread of highly pathogenic H7:N3 avian influenza among commercial poultry in Abbotsford, BC.	Preliminary results expected in October 2005
The BC Avian Influenza Outbreak: atmospheric transport as a possible propagation mechanism.	Preliminary results expected in June 2005
National serological survey for avian influenza in the Canadian domestic poultry industries	Survey to commence in the spring of 2005
Nationwide survey of waterfowl for avian influenza	Discussions underway
The role of backyard flocks in the spread of avian influenza	Preliminary results expected in October 2005
Evaluation of testing regimes employed during the outbreak	Preliminary results expected in October 2005
Evaluating human, livestock and critical infrastructure exposures to biological agents (mosquito larvicide) applied by conventional spray techniques- Principal Investigator: University of Victoria (project will help to establish generic aerosol sampling techniques for field situations)	Grant application underway
On site composting for bio-containment and safe disposal of infectious animal carcasses and manure (project geared to build on the outbreak experience and address current knowledge gaps)	Grant application underway

6.0 List of Investigation Reports and Contributors

1-Literature review of survival of avian influenza virus in aerosol/dust. Pascal Moreau, Animal Health Risk Analysis, Science Branch, May 2004.

2-Literature review of highly pathogenic avian influenza virus survival in manure. Pascal Moreau, Risk Analyst and Scientific Advisor, Animal Health Risk Analysis, Science Branch, March 2004.

3-Literature review of avian influenza survivability in water. Victoria Bowes, Poultry Pathologist, BC Ministry of Agriculture Food and Fisheries, April 2004.

4-Case series review: assessment of the role of wind in disease transmission. Nancy DeWith, Epidemiologist, CFIA contract, April 2004.

5-Case series review: assessment of the role of ground and surface water in transmission of avian influenza. Nancy De With, Epidemiologist, CFIA contract, May 2004.

6-Case series review: assessment of the role of service providers in the transmission of avian influenza. Connie Argue, Veterinarian, Peter Brassel, Veterinarian, Sandra Shearer, Veterinarian, CFIA. April 2004.

7-Case Series review: assessment of the role of hatcheries as a source of avian influenza. Lindsey Garber, Epidemiologist, CEAH, USDA, April 2004.

8-Case Series review: assessment of the role of feeds and feed mills in the transmission of avian influenza. Blaine Thompson, Veterinarian, CFIA. March 2004.

9- Risk of CFIA staff transferring avian influenza to uninfected flocks as a result of blood sampling and depopulating infected flocks. Sandra Shearer, Veterinarian, CFIA. April 2004.

10-Surface wind conditions in the Fraser Valley during the avian influenza (January 11-April 2, 2004), Stephanie Meyn, Air Quality Meteorolgist, BC Ministry of Water Land And Air Protection. April 2004.

11-Evaluation for the potential of dust borne barn to barn transmission of highly pathogenic avian influenza in the Fraser Valley, British Columbia. in March 2004. Carolyn Dubé, Epidemiologist , Animal Health and Production Division and Pascal Moreau, Risk Analyst and Scientific Advisor, Animal Health Risk Analysis, Science Branch, April 2004.

12-The role of wild birds as a source of low pathogenic avian influenza (H7N3). Victoria Bowes, Poultry Pathologist, BC Ministry of Agriculture Food and Fisheries, April 2004.

13-Wild birds as a source of transmission of avian influenza in the Fraser Valley, British Columbia. Pascal Moreau, Risk Analyst and Scientific Advisor, Animal Health Risk Analysis Unit, Science Branch, April 2004.

14-Report on the avian influenza aerosol sampling trial in the British Columbia Fraser Valley April 9-19, 2004. Laurie Schofield, Jim Ho, Bill Kournikakis, Research Scientists, Defence R and D Canada- Suffield, Department of National Defence, June 2004.

15-Comprehensive report on the 2004 outbreak of High Pathogenicity Avian Influenza (H7N3) in the Fraser Valley of British Columbia, Canada. Wayne Lees, Epidemiologist and Lawana Chown, student, Animal Disease Surveillance Unit, June 2004.

16-Avian Influenza. CAHNet Bulletin Edition 9. Animal Disease Surveillance Unit. Winter 2004.

17-Report on the Canadian Poultry Industry Forum of October 27 and 28, 2004, Abbotsford, B.C. Ross Hudson and Lynn Elwell, CFIA, December 2004.

18-Post-Incident Review of the CFIA's Response to the 2004 Avian Influenza Outbreak in B.C. Corporate Evaluation Directorate. CFIA. December 9, 2004. Draft.

7.0 Acknowledgments

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