HNF-64747
Revision 0

# Hanford Site Bee Nest Box Monitoring Report for Calendar Year 2019

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-09RL14728


**P.O. Box 650**
**Richland, Washington 99352**


**Approved for Public Release**
**Further Dissemination Unlimited**

This page intentionally left blank.

HNF-64747
Revision 0

# Hanford Site Bee Nest Box Monitoring Report for Calendar Year 2019

E. S. Norris, MSA

Mission Support Alliance
Richland, WA

Date Published
April 2020

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

**P.O. Box 550**
**Richland, Washington 99352**

APPROVED
By Sarah Harrison at 11:47 am, Jun 04, 2020

Release Approval Date

# TABLE OF CONTENTS



# FIGURES

# 1.0 INTRODUCTION

This report summarizes the results of the first year of monitoring bee nest boxes on the Hanford Site. Twenty bee nest boxes were installed as a component of compensatory mitigation for the installation of the L-894 water line between the 200-East and 200-West Areas of the Hanford Site. The goal of this compensatory mitigation is to replace lost nesting habitat for above-ground nesting bees in a mature sagebrush ecosystem. Annual monitoring will track the condition and occupation of the bee nest boxes to determine if the compensatory mitigation was successful and to identify best practices when replacing nesting habitat for native bees.

## 1.1 PURPOSE AND NEED

Pollinators are vital to the health of native environments (Potts et al. 2010). By enabling successful plant reproduction, pollinators support the health of nearly all other organisms in the environment that rely on healthy plant populations. Bees are the most important group of pollinators worldwide (Kearns et al. 1998; Michener 2007) and are the primary pollinating species of the Columbia River Basin (Tepedino and Griswold 1995). Within the last century, rapid declines in both wild and managed bee populations have been recorded throughout the world (Kearns et al. 1998; Goulson et al. 2005; Biesmeijer et al. 2006). Declining bee populations put plant populations at risk of declining, which has the potential to affect the entire food web and disrupt ecosystems.

Habitat loss and fragmentation from human activities is one of the largest risks to pollinator populations. Habitat fragmentation reduces both pollinator abundance and diversity (Rathcke and Jules 1993). At the Hanford Site, human-caused habitat fragmentation most often occurs when vegetation is removed from natural areas to support project activities. This removal of vegetation results in the loss of both food and nesting resources for bees.

Replacing lost nest areas is vital to protect bee populations. Nesting area availability can be the driving factor in solitary bee population sizes (Steffan-Dewenter and Schiele 2008). Nesting resources for bees include hollow twigs, woody shrubs like sagebrush (*Artemisia tridentata*), and bare patches of ground. The removal of vegetative structures and disturbance of bare ground can kill nesting bees and removes potential nesting sites. The limited ranges of bees make local changes in habitat structure especially detrimental to population health, as the majority of wild, solitary bees have ranges of a few hundred meters (Gathmann and Tscharntke 2002).

The Hanford Site Pollinator Study identified a number of best management practices to help support pollinator populations on the Hanford Site (HNF-62689). In areas where vegetation is disturbed to support project activities, the study recommends replacing pollinator habitat by restoring with native flowering plants. This study also recommended additional restoration actions to replace bee nesting habitat.

Bee nest boxes are designed to replace lost nesting resources by providing areas for solitary bees to nest. Various styles of bee nest boxes have been installed throughout the Hanford Site in an effort to increase available nesting habitat in areas where natural habitat has been removed.

The purpose of bee nest box monitoring is to collect data on bee usage of the nest boxes. These data will be used to determine if bee nest box installation is an effective way to replace lost bee nesting habitat in disturbed areas. Two different styles of bee nest box have been installed. The data from this monitoring effort will be used to compare bee usage of the different styles of nest boxes and to determine if there is a preferred style. Additionally, these styles include different nesting materials, and this monitoring effort will be used to determine if there is a preferred nesting material.

In addition to data collection, bee nest box monitoring will include checking the bee nest boxes for structural defects, ensuring the boxes are clean, and recording and developing an action plan for any issues with the boxes. The bee nest boxes will be monitored for 5 years after installation to determine their effectiveness; the boxes will be maintained, as needed, into the future.

For additional information about pollinators found on the Hanford Site, see the *Hanford Site Pollinator Study* (HNF-62689).

## 1.2 REGULATORY DRIVERS

### 1.2.1 Federal Laws and Policy

The U.S. Department of Energy, Richland Operations Office (DOE-RL) conducts ecological monitoring on the Hanford Site to collect and track data needed to ensure DOE-RL compliance with an array of laws and policies. Ecological monitoring data provide baseline information about the plants, animals, and habitats under DOE-RL stewardship required for decision making under the *National Environmental Policy Act* and *Comprehensive Environmental Response, Compensation, and Liability Act*.

**1.2.1.1 Presidential Guidance and Memoranda.** The 2014 presidential memorandum "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators" (79 FR 35903-35907) calls for immediate action to be taken by land-owning federal departments to prevent further pollinator population decline. This memorandum called for the establishment of a Pollinator Health Task Force that includes representatives from over 15 federal agencies, including the U.S. Department of Energy. This task force developed the *Pollinator Research Action Plan* (Pollinator Health Task Force 2015a) that outlines key priorities and goals to improve pollinator health. One of the goals of this plan is to restore or enhance 2.8 million ha (7 million ac) of pollinator habitat on federally-owned land (Pollinator Health Task Force 2015b). Section II of the *Pollinator Research Action Plan* is especially relevant to future pollinator habitat improvement work on the Hanford Site.

Section II addresses the need for increased and improved pollinator habitat. Current understanding of pollinator habitat requirements is limited. A key priority research theme of this section is "identifying viable approaches to restore and create pollinator habitat," (Pollinator

Health Task Force 2015a). Installing bee nest boxes and monitoring their effectiveness works toward the goal of restoring and creating pollinator habitat.

**1.2.1.2 U.S. Department of Energy Orders and Guidance Documents.** The Department of Energy Pollinator Protection Plan (Pollinator Health Task Force 2015b, Appendix E) directs the adoption of Best Management Practices (BMPs) for pollinator health. The U.S. Department of Energy is a land-owning agency and will assess each site to determine if implementing the BMPs is appropriate. As per the plan, the commitment to enhance, preserve, and protect pollinator habitat according to BMPs is consistent with Section 3, Subsection (a) of 79 FR 35903-35907, which calls for

> "the development of a plan to enhance pollinator habitat and the implementation of a plan to manage lands and facilities under the auspices of the Department to enhance pollinator health on those lands."

Installing and monitoring bee nest boxes falls under this plan as it contributes to the creation and enhancement of pollinator habitat.

### 1.2.2 Hanford Site Management Guidance

DOE/RL-96-32, *Hanford Site Biological Resources Management Plan* (BRMP) is identified by the DOE/EIS-0222-SA-01, *Hanford Comprehensive Land-Use Plan* (CLUP) as the primary implementation control for managing and protecting natural resources on the Hanford Site. According to the CLUP, the BRMP

> "provides a mechanism for ensuring compliance with laws protecting biological resources; provides a framework for ensuring that appropriate biological resource goals, objectives, and tools are in place to make DOE an effective steward of the Hanford biological resources; and implements an ecosystem management approach for biological resources on the Site. The BRMP provides a comprehensive direction that specifies DOE biological resource policies, goals, and objectives."

DOE-RL places priority on monitoring those plant and animal species or habitats with specific regulatory protections or requirements; that are rare and/or declining (e.g., federal or state listed endangered, threatened, or sensitive species); or are of significant interest to federal, state, or Tribal governments or the public. Pollinators are of significant interest to the federal government, as demonstrated by the formation of the Pollinator Health Task Force. The health of pollinators, especially honey bees, is of public concern and has been the focus of increased media and public attention in the past 10 years.

The BRMP provides guidance regarding compensatory mitigation in scenarios where natural resources cannot be avoided, impacts cannot be minimized, and the resources cannot be rectified in place. Enhancing habitat quality can satisfy compensatory mitigation requirements if the mitigation is successful. The bee nest boxes monitored in 2019 were installed as a component of compensatory mitigation for the installation of a waterline between the 200-East and 200-West

Areas of the Hanford Site. Monitoring is a critical component in determining the success of compensatory mitigations.

### 1.3 GOALS AND OBJECTIVES

The specific objectives of this monitoring report are to:
- Provide first-year data for bee nest box occupation
- Determine the effectiveness of different bee nest boxes at replacing lost bee nesting habitat
- Recommend actions to increase bee nest box occupation.

This monitoring report is the first report in a multi-year effort to analyze the effectiveness of bee nest boxes replacing bee nesting habitat. The results of this effort will help inform future bee nesting habitat restoration and can be used in larger pollinator habitat restoration projects.

### 1.4 SCOPE OF MONITORING REPORT

The remaining sections of this monitoring report cover the following topics:
- **Section 2** summarizes the nesting biology of native bees in relation to the Hanford Site
- **Section 3** describes the location and installation of the bee nest boxes monitored in 2019
- **Section 4** defines the methods used to monitor bee nest box occupation
- **Section 5** describes the results from first-year bee nest box occupation monitoring
- **Section 6** discusses the results and provides recommendations for future monitoring
- **Section 7** lists the literature cited throughout this report.

## 2.0 NESTING BIOLOGY OF NATIVE BEES

Native bees are the primary insect pollinators of the Columbia River Basin and over 600 species are known to the region (Tepedino and Griswold 1995). Through pollination, these insects enable healthy plant reproduction and support organisms that rely on flowering plant populations for food and shelter. Bees are most abundant in arid environments similar to the environment of the Columbia River Basin (Linsley 1958; Koh et al. 2016). The Hanford Site Pollinator Study, performed in 2017, found over 25 groups of bee on the Hanford Site (HNF-62689). Habitat loss, alternation, and fragmentation are major threats to populations of native bees (Kearns et al. 1998). Removal of bee habitat includes both the removal of foraging resources and of nesting resources.

The majority of most solitary bee lifecycles are spent within the nest. Adult bees emerge in the spring and summer, and spend the time they are active mating, drinking nectar, collecting pollen, and provisioning their nests. Most bees lay eggs within individual nest cells and provision the cell with a pollen loaf that the larva will eat. After the nest cell is sealed, the egg undergoes a complete metamorphosis and develops into an adult. This process can be halted in the prepupal stage so that the bee does not develop too early and can emerge during the proper time in the spring or summer. Some bee species are bivoltine, meaning they can produce multiple generations in 1 year. Most bees only spend 3 to 6 weeks of their lives as active adult bees outside of the nest (Wilson and Messinger Carril 2016).

Bee nesting strategies vary depending on the species. Unlike European honey bees (*Apis mellifera*), native bees are typically solitary and do not nest in a colony. Native bee nests may be aggregated close together, but in most species this is likely due to availability of nesting resources rather than social behaviors (Mader et al. 2010). Native bees in the Columbia River Basin nest in an array of substrates, the two most common being soil and wood or debris (Tepedino and Griswold 1995). Soil nesting bees found on the Hanford Site in a 2017 study included bees in the genera *Andrena*, *Perdita*, *Diadasia*, *Eucera*, *Melissodes*, *Anthophora*, *Hapropoda*, *Colletes*, *Halictus*, *Lasioglossum*, and *Agapostemon*, along with their associated cleptoparasites (HNF-62689; Wilson and Messinger Carril 2016). Above-ground nesting bees typically nest in open cavities or in holes bore into wood by other insects. Above-ground nesting bees found on the Hanford Site in a 2017 study included bees in the genera *Lithurgopsis*, *Osmia*, *Dianthidium*, *Paranthidium*, *Anthidium*, and *Megachile* (HNF-62689).

Above-ground nesting bees are known to nest in dead woody material, hollow stems, cracks in rocks, and in other substrates with pre-existing cavities (Murray et al. 2009). In shrub-steppe environments, big sagebrush (*Artemisia tridentata*), antelope bitterbrush (*Purshia tridentata*), and spiny hopsage (*Grayia spinosa*) may provide nesting habitat. Ground nesting bees nest in bare patches of soil that are typically in exposed, sunny spots (Wilson and Messinger Carril 2016). With some exceptions, the type of soil that ground nesting bees prefer is largely unknown (Tepedino and Griswold 1995).

Nesting habitat is believed to be a limiting factor in the size and health of native bee populations and can determine overall bee community composition (Steffan-Dewenter and Schiele 2008; Potts and Roberts 2005). One of the greatest threats to bee populations is the removal of nesting material (Tepedino and Griswold 1995). Targeted habitat restoration combats this threat and is one of the tools most commonly used to help support bee populations. Taking a holistic approach to native bee habitat restoration means restoring both foraging and nesting resources.

# 3.0 BEE NEST BOXES INSTALLED IN 2019

In 2019, a waterline (L-894) was constructed between the 200-East and 200-West Areas of the Hanford Site. This waterline resulted in the removal of mature shrub-steppe habitat and subsequent loss of above-ground nesting resources for native bees. Though the area was replanted, an access road spans the length of the waterline, resulting in permanent loss of shrub-steppe habitat. Twenty bee nest boxes were installed with the goal of replacing lost bee nesting habitat and studying the effectiveness of different bee nest box designs as a replacement habitat. This habitat restoration effort directly targeted above-ground and cavity nesting bees. Ground-nesting bee habitat was not targeted as little is known about the habitat requirements of ground-nesting bees apart from the availability of bare ground (Tepedino and Griswold 1995). Significant patches of bare ground were present throughout the replanted areas of the waterline.

The twenty bee nest boxes were installed the first week of July 2019. The boxes were spaced approximately 200 m (656 ft) apart along the waterline and located in the margin where the revegetation site met the natural habitat. Figure 1 shows the spacing of the bee nest boxes along the waterline.

Two differing designs of bee nest boxes were installed as part of 2019 efforts in order to study the effectiveness of different box designs. Design A contains both drilled holes and nest tubes as nesting habitat options. Design A had an average of 16 drilled holes and 67 nest tubes available per box. Design B contains drilled holes, nest tubes, pinecones, wood pieces, and slots for butterfly use. Design B had an average of 64 drilled holes and 198 nest tubes available per box. Both boxes were installed on U-Channel posts approximately 1 m (3.28 ft) off the ground and securely fastened so they did not move in the wind. The designs were installed in an alternating pattern from west to east, starting with Design A in the west. Ten boxes of each design were installed.

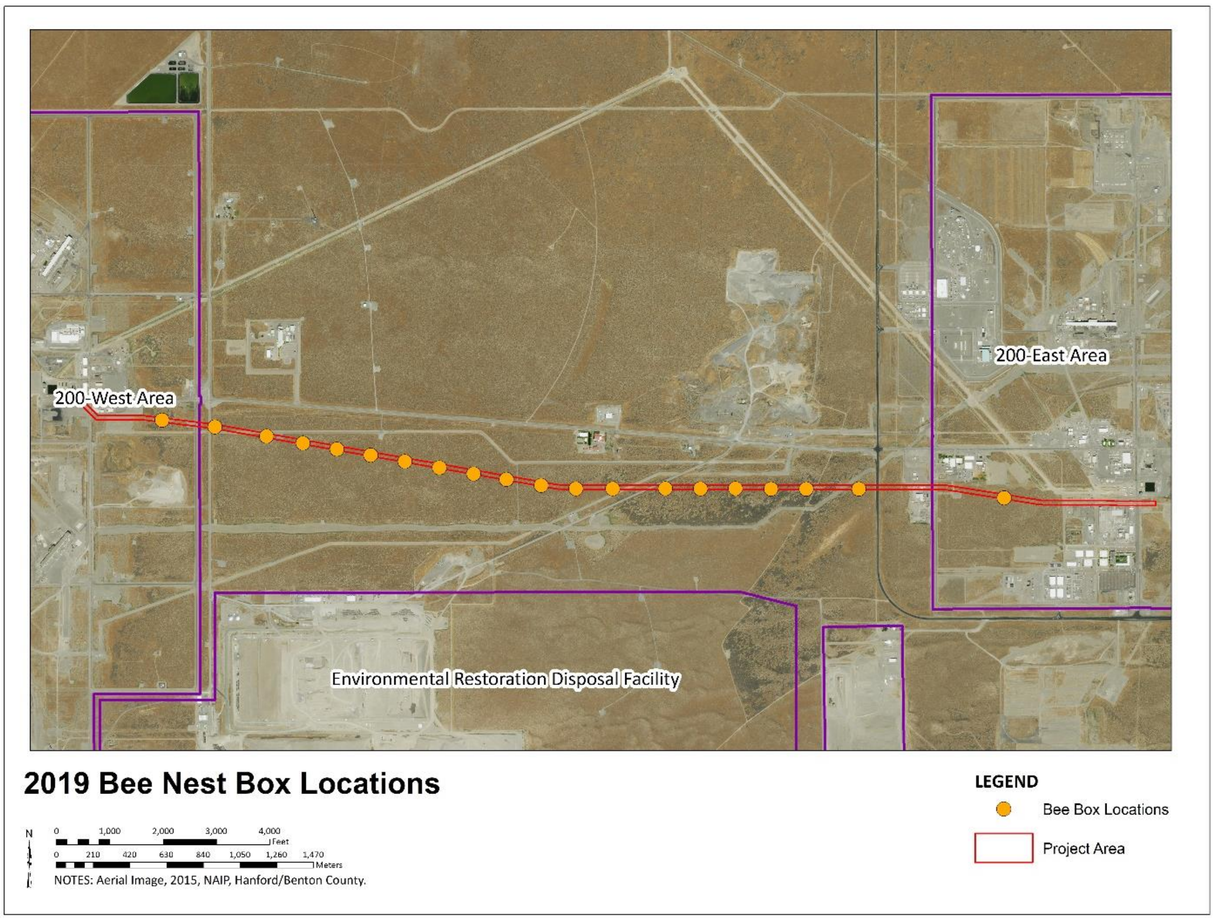


**Figure 1. Locations of Bee Nest Boxes Installed in 2019.**

**Figure 2. Design A (Left) and Design B (Right) Bee Nest Boxes (Not to Scale).**

# 4.0 MONITORING METHODS

Nest box monitoring occurs after the active season for native bees has completed, approximately mid- to late-October at the Hanford Site (HNF-62689). The goal of bee box monitoring is to determine box occupation by counting the number of nests in each box. This relatively simple method allows researchers to determine box effectiveness, compare different styles of boxes and nesting material, and to compare variation in year-to-year occupation. Occupation monitoring involves visiting each box and counting the total number of nest tubes/holes and the number of occupied nest tubes/holes. Occupied nest holes are identified with the cut pieces of leaf or mud plugging the nest tubes/holes (Figure 3). This information along with a description of the box style, condition, and any noticeable changes were noted.

Some species of bees are bivoltine and can have multiple generations in 1 year. In some cases the nest cells that were created in the spring and early summer may have already produced offspring. These cells will have remnants of cut leaves around the inside of the tube that will have a hole eaten through the middle (Figure 4). These cells will be counted as occupied during occupation monitoring to reflect their use earlier in the year. Anecdotal observations have noted bees reusing the cells where bees emerged earlier in the season. This was not the case in 2019 monitoring as the nest boxes were not installed until July but will be considered in future monitoring efforts.

Design B includes nesting areas that are not tubes or drilled holes. These areas can consist of stacked debris, pine cones, or slots. If there is evidence of bee nesting in these areas, it was recorded on the field form. Evidence may consist of mud added to the area or leaves blocking an opening in the debris. If there is evidence of other insects using the nest box, it was recorded and the type of insect identified, if possible. Examples of this include finding a used wasp nest, cocoon, or chrysalis attached to or inside the box. Use of the box by other animals such as finding bird excrement on top of the box or scratches on the side of the box were recorded and signs of predation were looked for.

After the nest box was checked for insect and animal use, close-up pictures were taken of the nest boxes for documentation. Other information to record about the bee boxes included the condition of the tube/hole openings. Openings with splinters or other obstructions at the entrance may be less likely to be used by bees. Occupation monitoring will be repeated annually for 5 years following installation to determine success.

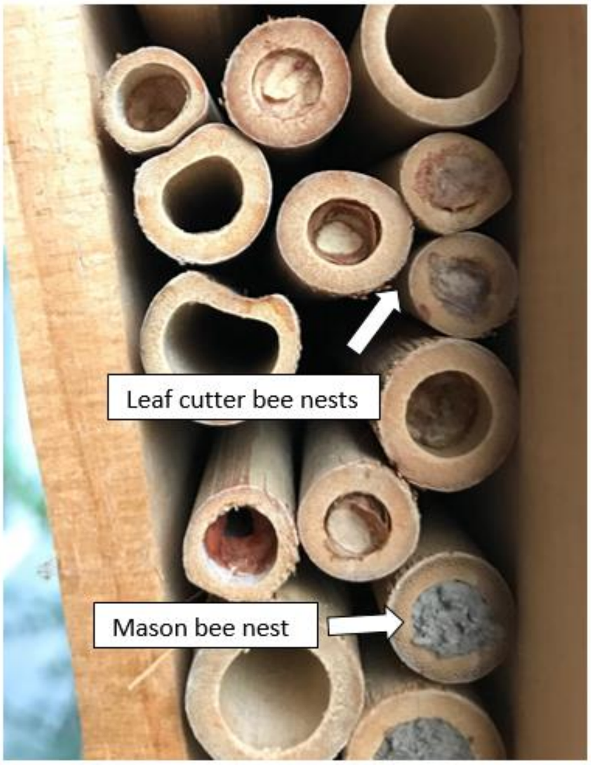


**Figure 3. Occupied Bee Nest Box Showing Leaf Cutter Bee and Mason Bee Nests.**


**Figure 4. Occupied Bee Nest Box Showing Previously Occupied Nest Cell of Leaf Cutter Bee.**

# 5.0 2019 MONITORING RESULTS

Quantitative data collected over multiple years is necessary to evaluate the effectiveness of bee nest boxes in recreating bee nesting habitat for above-ground nesting bees. The first year of monitoring for the bee nest boxes installed in July 2019 took place on December 9, 2019.

## 5.1 OCCUPATION DATA

Of the 20 bee nest boxes surveyed, 5 contained nests at the time of monitoring. Two of the occupied nest boxes were Design A, and three were Design B. The nest boxes were numbered 1 through 20 from west to east; the occupied nest boxes were numbers 1, 2, 9, 18, and 20. Boxes 1, 2, and 20 were the closest nest boxes to areas heavily impacted by human activity.

Within the 5 boxes that were occupied, 15 nests[1] were recorded. Thirteen of these nests were within drilled holes, and two were within the nest tubes. Seven of the 15 nests were created with

[1] For the purposes of this monitoring effort, one nest refers to one occupied nest tube or drilled hole. Within each of these nests, one would expect to find multiple nest cells.

mud (47%), 6 were created with leaves (40%), and 2 were created with a cellophane-like substance (13%) (Figure 5).

Of the 15 recorded nests, 6 nests were in Design A boxes (40%) and 9 nests were in Design B boxes (60%). All of the nests in the Design A boxes were located in drilled holes while the Design B boxes had seven nests in drilled holes and two nests in nest tubes.

Though it appears the larger nest box design (Design B) provides far more nesting habitat, monitoring results noted that many of the Design B nest holes and tubes were obstructed by split wood or not properly drilled. Design B averaged 198 nest tubes per box, with 72 of those tubes being unobstructed. Design A averaged 67 nest tubes per box, with 66 of those tubes being unobstructed. Design B averaged 64 drilled holes per box, with 37 of those being unobstructed. Design A averaged 16 drilled holes per box, with all 16 of those being unobstructed.

For all of the Design A boxes, 822 nest spots (both nest tubes and drilled holes) were unobstructed. Of these, six were occupied, resulting in 0.7% total occupation. Of the drilled holes available in Design A nest boxes, six were occupied, resulting in 3.8% occupation of Design A drilled holes. No nest tubes were used in Design A boxes, resulting in 0% occupation of Design A nest tubes.

For all of the Design B boxes, 1,084 nest spots (both nest tubes and drilled holes) were unobstructed. Of these, nine were occupied, resulting in 0.8% occupation. Of the drilled holes available in Design B, seven were occupied, resulting in 1.9% occupation of Design B drilled holes. Of the nest tubes available in Design B nest boxes, two were occupied, resulting in 0.3% occupation of Design B nest tubes. No insect use was detected in the alternative substrates of Design B.

When considering total use, 20% of Design A and 30% of Design B nest boxes were occupied by bees in 2019 monitoring. Of the bee nest boxes installed in 2019, 25% contained bee nests.

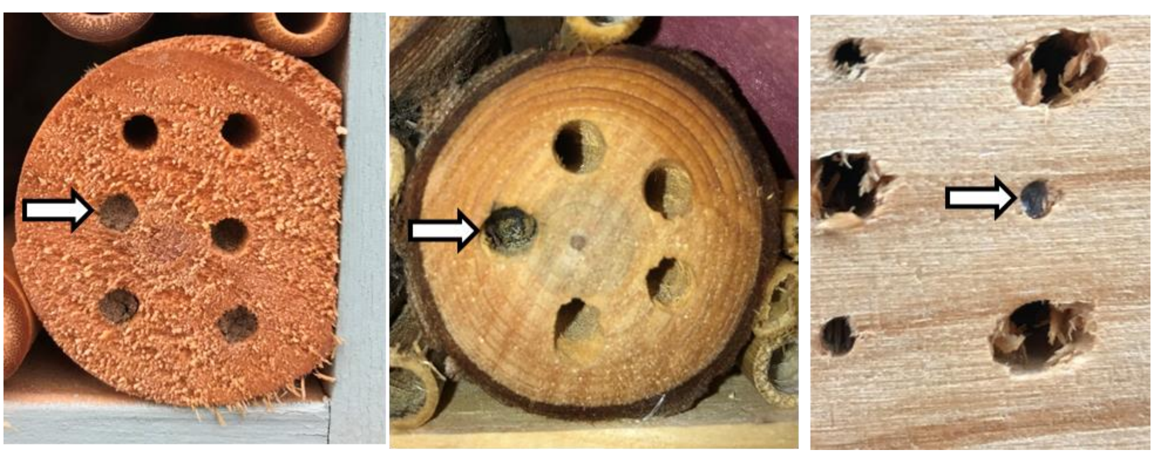

**Figure 5. Occupied Drilled Holes Filled with Mud (Left), Leaves (Middle), and a Cellophane-Like Substance (Right).**

### 5.2 CONDITION DATA

Weather and moisture damage has affected the wooden roofs of Design B. Nine of the 10 Design B nest boxes have split roofs, as seen in Figure 6. This can potentially allow moisture into the nesting area, which is not desirable. None of the Design A nest boxes had split roofs. No apparent damage from other animals or predation was noted on the bee nest boxes. Thirteen of the 20 boxes had bird excrement on the roof and appeared to have been used as perches.

**Figure 6. Weather Damage on a Design B Nest Box.**

## 6.0 DISCUSSION AND RECOMMENDATIONS

First-year monitoring of the bee nest boxes installed in 2019 provided data that will be used to analyze trends and the effectiveness of the bee nest boxes in the years to come.

One of the goals of analyzing bee nest box occupation was to determine if the nest boxes were effective at replacing bee nesting habitat. A complicating factor in first-year monitoring of the nest boxes was the timing of installation. The nest boxes were installed in July 2019, approximately 3 months after the active season for bees had begun. The majority of bee activity at the Hanford Site occurs in June (HNF-62689) and the late installation of these boxes may have resulted in lower occupation and skewed the results of first-year monitoring. Notably, in the Hanford Site Pollinator Study the majority of bees in the *Osmiini* (mason bee) and *Megachile* (leaf-cutter bee) groups were collected before July. These two groups of bee are specifically targeted by bee nest boxes and were likely missed due to the late installation of the nest boxes.

Though 25% of the bee nest boxes were occupied, less than 1% of the available nesting spaces were used. This number is expected to increase as the boxes are available during the entire active season for bees. Percent occupation of available nesting space was nearly identical at Design A and Design B, with 0.7% and 0.8% occupation, respectively. Design A offered an average of 82 unobstructed holes per box, while Design B offered an average of 109 unobstructed holes per box. By first-year monitoring, approximately 5 months after installation, Design B was showing signs of weathering. Future monitoring will be necessary to determine if Design B can be used for multiple years.

Results from 2019 show the drilled holes being used at a higher rate than the nest tubes. This could be due to a number of factors, including drilled hole diameter, length, increased insulation, and/or the type of wood. There is not enough data at this time to point towards one or more factors as influencing bee preference, and there is the chance that this perceived preference is due to chance. More monitoring is required before coming to any conclusion. It is recommended that future monitoring measures the diameter of the occupied holes to determine size preference and inform future bee nest box designs.

There was a fairly even distribution of leaf-filled versus mud-filled nests. This ratio will likely change in future monitoring years when the nest boxes are available for the entire active season. The presence and distribution of leaf-filled and mud-filled nests may indicate the types of bees that are utilizing the nest boxes and can demonstrate which bees are benefiting from the replacement habitat. Leaf-cutter bees in the *Megachile* genus are likely occupying the leaf-filled nests, and mason bees in the family *Osmiini* are likely occupying the mud-filled nests.

Two nests appeared to be made from a cellophane-like substance in Bee Nest Box 2. A number of bees use cellophane-like secretions to line their nest cells, including bees in the Colletidae family. *Hylaeus* species nest in pre-existing holes and line their nests with a cellophane-like substance, they are relatively common in the Columbia Basin and were found on the Hanford Site in a 1997 insect survey (Zack 1997). This species may be creating the cellophane-like nests in Bee Nest Box 2.

The occupied bee nest boxes were numbers 1, 2, 9, 18, and 20 (Figure 7). Boxes 1, 2, and 20 were all the closest to areas of high human activity and environmental disturbance. The lack of alternative bee nesting habitat in the areas surrounding boxes 1, 2, and 20 may have contributed to the higher occupation of those boxes. Continued monitoring may reveal trends in bee nest box occupation near areas of heightened human activity.

Given the low occupation of the nest boxes in first year monitoring and the late installation of the bee nest boxes, it is recommended that the boxes be left in place for an additional season rather than be replaced. If the roofs of Design B continue to weather to a point that they no longer protect the nesting habitat into the following season, they will need to be replaced. The bee nest boxes can only be replaced if there are no active bee nests within them. If replacement is needed, it is recommended that the boxes are replaced with Design A, which appears to be more weather resistant. When left in place for a full season, bee nest boxes will be cleaned or replaced after nesting bees have emerged. Due to low usage in 2019, the bee nest boxes will be left in place for an additional season.

Future monitoring may reveal that drilled holes are more attractive to nesting bees in the area where the bee nest boxes are installed. If this is the case, the current designs may be replaced with boxes with larger numbers of drilled holes. It may be the smaller diameter of the drilled holes that are attracting more nesting bees. If this is the case, the current designs may be replaced with boxes with smaller nesting tubes and similarly-sized drilled holes in order to attract more nesting bees. Both possibilities need to be supported by more monitoring information before any changes are made.

The 20 bee nest boxes monitored in 2019 were installed as a compensatory mitigation measure to compensate for lost nesting habitat. The boxes had only been available for part of the active pollinator season, so the effectiveness of the compensatory mitigation action cannot be fully evaluated until the second year of monitoring.

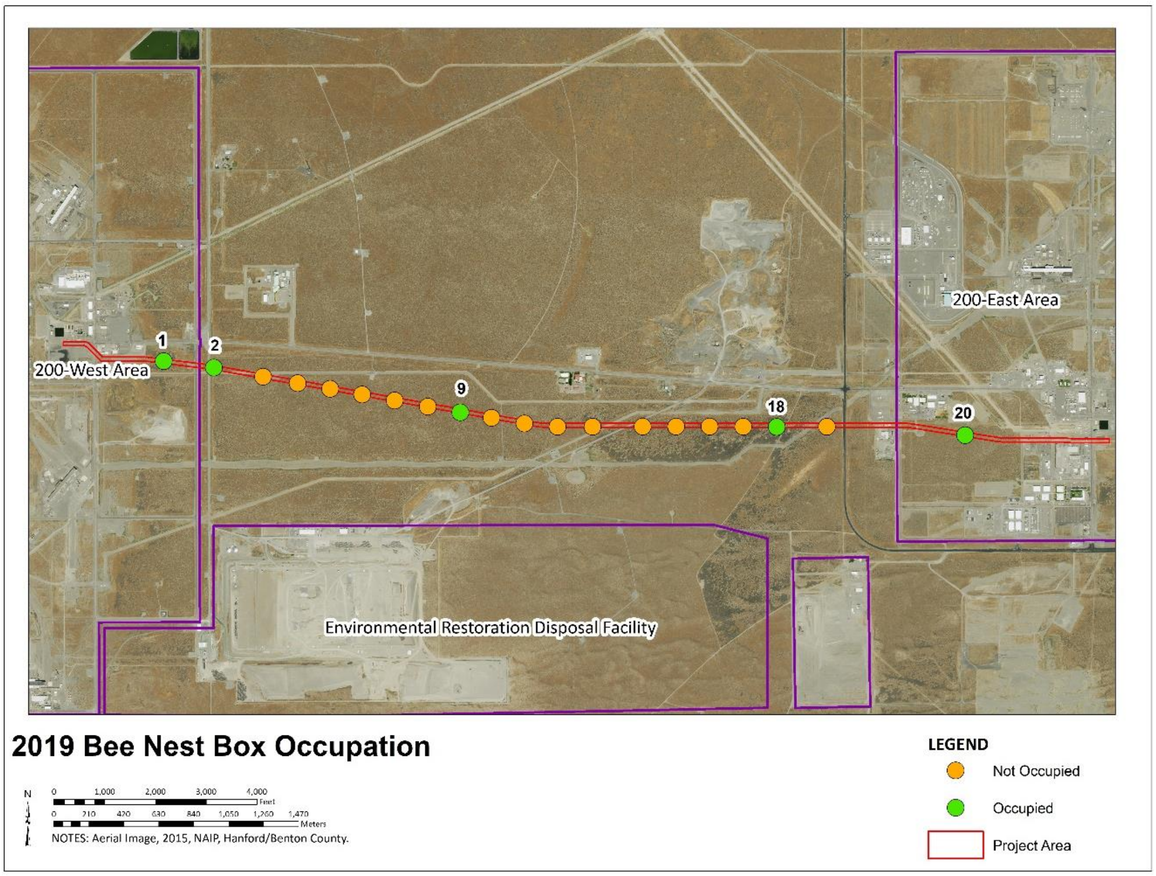


**Figure 7. Locations of the Occupied Bee Nest Boxes (1, 2, 9, 18, 20) in December 2019.**

# 7.0 REFERENCES

79 FR 35903-35907, “Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators,” *Federal Register* Volume 79, Issue 121.

Biesmeijer, J. C., S. P.M. Roberts, M. Reemer, R. Ohlemuller, M. Edwards, T. Peeters, A. P. Schaffers, S. G. Potts, R. Kleukers, C. D. Thomas, J. Settele, and W. Kunin, 2006, “Parallel Declines in Pollinators and Insect-Pollinated Plants in Britain and the Netherlands,” *Science* Vol. 313, No. 5785, pp. 351-354. Online at: https://ncbnaturalis.nl/media/medialibrary/2013/08/2006_biesmeijer_pollinator_diversity.pdf.

*Comprehensive Environmental Response, Compensation, and Liability Act*, 42 U.S.C. 9601 et seq.

DOE/RL-96-32, 2011, *Hanford Site Biological Resources Management Plan*, current revision, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Online at: https://www.hanford.gov/files.cfm/DOE-RL-96-32-01.pdf.

DOE/EIS-0222-SA-01, 2008, *Hanford Comprehensive Land-Use Plan*, U.S. Department of Energy, Washington, D.C. Online at: https://www.energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/EIS-0222-SA-01-2008.pdf.

Gathmann, A., and T. Tscharntke, 2002, “Foraging Ranges of Solitary Bees,” *Journal of Animal Ecology*, 71: 757-764. Online at: https://besjournals.onlinelibrary.wiley.com/doi/epdf/10.1046/j.1365-2656.2002.00641.x.

Goulson, D., M. E. Hanley, B. Darvill, J. S. Ellis, and M. E. Knight, 2005, “Causes of Rarity in Bumblebees,” *Biological Conservation* Vol. 122, pp. 1-8. Online at: https://pdfs.semanticscholar.org/828c/763e72e6dcea67c2f8f9b271b4abc04d8fe1.pdf.

HNF-62689, 2018, *Hanford Site Pollinator Study*, Rev. 0, Prepared for the U.S. Department of Energy, Richland, Washington. Online at: https://www.hanford.gov/files.cfm/FINAL_POLLINATOR_REPORT_HNF-62689_-_Rev_00_-_Copy-pages-4-115.pdf.

Kearns, C. A., D. W. Inouye, and N. M. Waser, 1998, “Endangered Mutualisms: The Conservation of Plant-Pollinator Interactions,” *Annual Review of Ecology and Systematics* Vol. 29, pp. 83-112. Online at: http://www.jstor.org/stable/221703?seq=1#page_scan_tab_contents.

Koh, Insu, Eric V. Lonsdorf, Neal M. Williams, Claire Brittain, Rufus Isaacs, Jason Gibbs, and Taylor H. Ricketts. 2016. *Modeling the status, trends, and impacts of wild bee abundance in the United States*. PNAS 113.1: 140-145. http://www.pnas.org/content/113/1/140.full.pdf

Linsley, E. Gorton. 1958. *The Ecology of Solitary Bees*. Hilgardia 27.19: 543-99. http://ucanr.edu/repository/fileaccess.cfm?article=152473&p=DEWBHP

Mader, E., Spivak, M., And E. Evans, 2010, "Managing Alternative Pollinators: A Handbook for Beekeepers, Growers, and Conservationists," *SARE Handbook 11*, NRAES-186. Online at: https://www.sare.org/publications/pollinators/pollinators.pdf.

Michener, C. D., 2007, *The Bees of the World*, 2nd ed. The Johns Hopkins University Press, Baltimore, Maryland.

Murray, T. E., Kuhlmann, M., and S. G. Potts, 2009, "Conservation Ecology of Bees: Populations, Species, and Communities," *Apidologie*, Vol. 40, pp. 211-236. Online at: https://www.apidologie.org/articles/apido/pdf/2009/03/m08162.pdf.

*National Environmental Policy Act*, 42 U.S.C. 4321 et seq.

Pollinator Health Task Force, 2015a, *Pollinator Research Action Plan*, The White House, Washington, D. C. Online at: https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/Pollinator%20Research%20Action%20Plan%202015.pdf.

Pollinator Health Task Force, 2015b, *National Strategy to Promote the Health of Honey Bees and Other Pollinators*, The White House, Washington, D. C. Online at: https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/Pollinator%20Health%20Strategy%202015.pdf.

Potts, S. G. and S. P. Roberts, 2005, "Role of nesting resources in organizing diverse bee communities in a Mediterranean landscape," *Ecological Entomology*, Volume 30 No. 1, pp. 78-85. Online at: https://www.researchgate.net/publication/227739175_Role_of_nesting_resources_in_organising_diverse_bee_communities_in_a_Mediterranean_landscape.

Potts, Simon G., Jacobus C. Biesmeijer, Claire Kremen, Peter Neumann, Oliver Schweiger, and William E. Kunin. 2010. *Global Pollinator Declines: Trends, Impacts and Drivers*. Trends in Ecology & Evolution 25.6: 345-53. https://www.researchgate.net/publication/41621021_Global_pollinator_declines_Trends_impacts_and_drivers

Rathcke, B. J. and E. S. Jules, 1993, "Habitat fragmentation and plant-pollinator interactions," *Current Science* Vol. 65 No. 3, pp. 273-277. Online at: https://www.researchgate.net/publication/202000327_Habitat_fragmentation_and_pollinator_interactions.

Steffan-Dewenter, I., and S. Schiele, 2008, "Do resources or natural enemies drive bee population dynamics in fragmented habitats?" *Ecology* Vol. 89 No. 5, pp. 1375–1387.

Online at: https://pdfs.semanticscholar.org/5ba8/7ac197236e8a1161fd51641a04a1a101908d.pdf?_ga=2.254242624.956091546.1581614444-1131747306.1581614444.

Tepedino, V. J. and T. L. Griswold, 1995, "The Bees of the Columbia Basin," *USDA-ARS Bee Biology & Systematics Laboratory*. Online at: https://www.researchgate.net/publication/242699897_THE_BEES_OF_THE_COLUMBIA_BASIN.

Wilson, Joseph S., and Olivia Messinger Carril. 2016. *The Bees in Your Backyard: a Guide to North America's Bees*. Princeton University Press.

Zack, R. S., 1997, "Entomological Diversity Inventory and Analysis at the Hanford Site: Report for the 1997 Field Season," Prepared for The Nature Conservancy of Washington, Seattle, Washington.