What's in WIPP?
Packaging TRU Waste to Enhance WIPP's Capacity - 16515

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ABSTRACT

Beginning in 1999, and continuing for 15 years, the US DOE Waste Isolation Pilot Plant (WIPP) repository successfully disposed of defense Transuranic (TRU) waste. Six of the originally planned ten disposal panels were filled before two unrelated accidents temporarily halted disposal operations in February 2014. Based on counting the gross volume of all containers emplaced in WIPP to date, a little more than half of the legislated volume capacity has been subscribed (91,000 cubic meters). This paper describes the many different packaging configurations that have been used to ship TRU waste to WIPP, and makes observations that may enhance the repository capacity when shipments resume.

The contents of shipments to WIPP are limited by many requirements of the repository waste acceptance criteria. These criteria derive from three primary sources; 1) the Certificate of Compliance (CoC), issued by the NRC for Type B shipping packaging used by WIPP; 2) The Hazardous Waste Facility Permit, issued by the New Mexico Environment Department; and 3) the WIPP facility's own Documented Safety Analysis (DSA), developed under DOE's regulation 10CFR830. To meet these criteria, various TRU waste forms have been packaged in different ways, with varying packaging efficiency.

Of course, there is an overall upper limit on WIPP's volume capacity that was legislated as part of the WIPP Land Withdrawal Act. The volume counted against this limit has been calculated by simply summing the volumes of individual payload containers shipped to and emplaced at WIPP. This method counts significant non-waste volumes inside the containers due to over-packing inner containers and partially filled containers. Without some change to how disposal volumes are calculated, or how waste is packaged, the amount of TRU waste yet to be shipped to WIPP could exceed the legislated capacity. Concepts to enhance the packaging efficiency of future waste shipments to WIPP are presented. Approximate estimates of the waste versus non-waste volumes that have been emplaced to date are discussed. This paper only considers contact handled TRU waste (i.e., contact dose rates < 2 mSv/hr).

INTRODUCTION

WIPP was legislatively authorized in 1979, following a long and rich US history of planning for permanent isolation of all long-lived radioactive wastes from the production of nuclear weapons in a deep geologic salt formation. Constructed during the 1980's, the facility was ready for disposal operations in 1988. Two decades passed from WIPP authorization to operation, with waste acceptance limited to only defense-related transuranic (TRU) waste. Full scale shipping and emplacement began March 1999. Numerous descriptions of the history, design, operation and regulatory oversight of WIPP have been published over the years, and are not repeated here. An excellent overview was published in Radwaste Solutions Magazine (May/June 2009), which devoted the entire issue to WIPP in recognition of the facility's tenth operating anniversary. For a detailed look at WIPP and its many attributes, along with a complete description of its operation, the reader is encouraged to review that issue [1].

With almost 15 years of successful and safe operations, the WIPP facility was suddenly shut down in February 2014 due to two unrelated accidents underground. A summary of these unfortunate events, their impact on America's only deep geologic repository, and the WIPP facility recovery process was presented at the Waste Management Symposium in 2015 [2].

The limit on the volume of waste that may be emplaced in WIPP is codified in the statutory record as 175,565 cubic meters (6.2 million cubic feet). That limit derives from a simple set of assumptions that originated in the controversial Environmental Impact Statement (EIS) process that occupied early WIPP planners in the 1970's [3]. As the project became more and more of a reality over the ensuing decades, the waste volume analyzed in the EIS process evolved into more and more of a limit, and eventually became WIPP's "capacity". The facility was designed and built in the 1980's with a layout and disposal room size that provided space for the volume of waste analyzed in the EIS. In practice, this layout and size could be adjusted to accommodate many times more (or less) volume. In 1992, the WIPP Land Withdrawal Act limited the waste volume allowed for disposal in WIPP by referring to the volume as a "capacity" [4]. It is important to note that the Land Withdrawal Act did <u>not</u> place limits on the total activity of contact handled TRU waste. This means that as long as the repository is able to comply with the disposal standards, there is no upper limit on the amount of transuranic isotopes that may be emplaced, but there is a limit on volume.

In the mid-1970s, the estimated amount of waste which would be "readily retrievable" from storage through 1986 at the Idaho National Laboratory site (mostly shipped there from the Rocky Flats site in Colorado) was about 2.4 million cubic feet (~68K cubic meters). It was also estimated that about 250,000 cubic feet per year (~7K cubic meters) was produced during the US nuclear weapons program. The EIS assumed that 2.4 million cubic feet from Idaho, plus 2/3 of the annual production amount from 1987-1990, and all of the annual production amount from 1990-2003 would be emplaced in WIPP. There was no justification for the choice of amounts, or durations provided in the EIS [3]. The EIS specifically did <u>not</u> analyze the disposal of the TRU waste stored retrievably at sites other than Idaho, <u>or</u> for the disposal of TRU waste buried at Idaho and other DOE sites. Yet it is the origin of the volume capacity with which WIPP must now comply, even though TRU waste from other sites, including waste from CERCLA removal actions, now contribute to the total TRU waste inventory bound for WIPP. Subsequent environmental analyses in the 1990's did evaluate impacts from other waste sources, but were still based on the 1980 EIS volume estimate.

Today, WIPP is a mature and regulated disposal system. Almost 35 years later, it is prudent to question how the seemingly arbitrary volume used in the 1980 EIS process compares with what we know about packaging and shipping TRU waste to WIPP. With the disposal capacity about 50% subscribed, what is the likelihood that the future TRU waste inventory will fit within WIPP's volume capacity? This is the primary subject of this paper.

But first, it is important to understand how the volume of waste is counted as it is emplaced at WIPP. Various programmatic WIPP requirements have been authorized by WIPP regulators, and specify the volume of waste to be counted when waste is received for disposal at WIPP. This volume is generally the payload container volume within the shipping containers. However, that "volume of record" also counts the volume that is unrelated to the actual volume of waste inside payload containers as described below.

OVER-PACKING INNER CONTAINERS AFFECTS REPOSITORY CAPACITY – COUNTING AIR AS WASTE

The TRU waste inventory across the DOE complex is widely diverse in origin and form. It includes glovebox debris, batch treatment residues, decommissioning & dismantlement materials, contaminated soils from environmental remediation projects, and many other forms. Some of the legacy inventory destined for WIPP is already containerized and stored, but much of that packaging was performed years ago, before packaging requirements were developed through a regulatory process to form what is now known as the WIPP Waste Acceptance Criteria (WAC). So a significant fraction of the already packaged TRU waste awaiting disposal at WIPP has had to be (and will continue to be) re-packaged to meet the WIPP WAC.

Over the years, a number of different containers for storing and shipping TRU waste have been developed. The most common waste container has been the 208-liter (55-gallon) standard DOT-7A drum. To date, more than 80,000 drums have been emplaced at WIPP. Three other payload containers used for over-packing inner containers, which are discussed more thoroughly below, are illustrated in Figure 1.

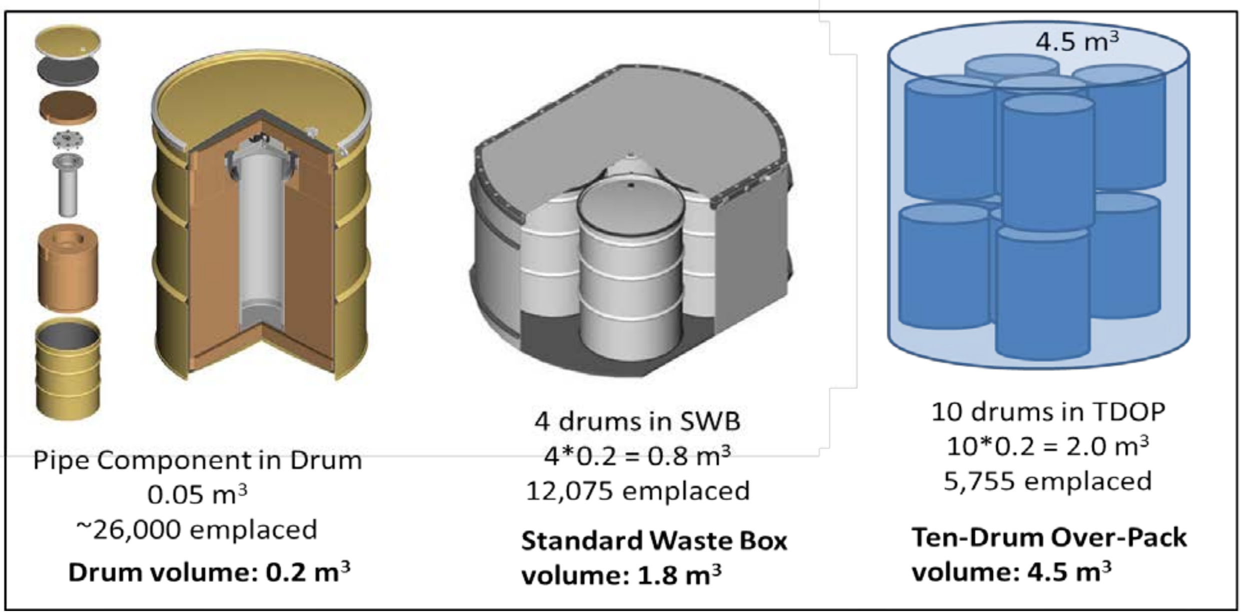

Fig. 1. Schematic illustration of three over-pack containers used for shipping waste to WIPP, with their respective volumes of the inner containers contrasted with the volume of the payload container (number emplaced through May 2013).

A common payload container used for shipping waste to WIPP is known as a standard waste box (SWB), which is almost exclusively used to over-pack 208-liter drums, four drums per SWB, as shown in the center of Figure 1. One motivation for over-packing 208-liter drums in SWB containers derives from limits imposed on the total fissile material authorized by the NRC that may be shipped in the licensed shipping containers, in this case the TRUPACT-II. The NRC limits the fissile content of a drum shipped to WIPP to less than 200g. This limit was also adopted in the Documented Safety Analysis for the repository by DOE. However, the CoC fissile limit for the total contents of a TRUPACT-II (WIPP's workhorse shipping container) is 325g. Some TRU waste generator sites have elected to ship legacy drums with more than 200g of fissile content by over-packing them into Standard Waste Boxes (SWB). This provides a configuration where a single drum (out of four) inside an SWB contains more than 200g, but forces the contents of the other seven drums (three more in the first SWB and four in the second SWB) to total to less than the difference between 325g and the first drum (<125 g). This allows the generator site to avoid re-packaging that drum (containing more than 200 g of fissile material), but it also results in a less efficient use of shipping resources, and space in the repository. The SWB volume is more than double the volume of the inner four drums. Therefore, when an SWB is emplaced at WIPP, the volume counted against that container is more than double the actual volume of drums over-packed within it.

Another reason 208-liter drums are over-packed into SWB payload containers is because many drums of legacy waste have corroded during retrievable storage over the decades. Drums of questionable integrity are over-packed in lieu of repackaging them into new drums to avoid potential worker exposure and cost.

Another payload container used for over-packing 208-liter drums that would otherwise challenge the WIPP WAC is known as the Ten-Drum Over-Pack (TDOP). The TDOP was originally developed for TRU waste at DOE's Savannah River Site. Much of the legacy stored waste there had been managed as drummed TRU waste, with many containers showing significant signs of corrosion. Also, when finally retrieved and non-destructively assayed, a significant fraction turned out to contain <3700 Bq/g (<100 nCi/g), which was less than the lower limit on the definition of TRU waste by the Land Withdrawal Act. To avoid repackaging these deteriorated drums with marginal activity concentrations of TRU isotopes, DOE decided to over-pack them in TDOP payloads and continue to manage this waste as a TRU waste stream. By placing a sufficient number of drums with transuranic isotopes >3700 Bq/g inside the TDOP, along with the remainder drums <3700 Bq/g, DOE was able to manage each resulting TDOP payload container as TRU waste, each with an overall content >3700 Bq/g, and ultimately ship them to WIPP. This practice was called "load management", and was eventually discontinued at the request of EPA. However, the TDOP payload container continued to be used at SRS and other sites to over-pack drums in order to avoid having to re-package them to comply with either shipping limits or the WIPP WAC.

Another over-pack example is the use of Ten-Drum Over-Packs (TDOP) to ship waste streams with high concentrations of Volatile Organic Compounds (VOC). This waste stream (at Idaho) has been packaged as ten 208-liter drums inside a TDOP, and shipped with one TDOP per TRUPACT-II. For shipping, multiple filter vents are installed in the TDOP to meet flammable gas limits of the CoC, but removed before emplacement in the WIPP underground to limit the resulting VOC concentrations in the underground. The TDOP total volume is more than twice that of the internal ten drums. Therefore, when a TDOP is emplaced at WIPP, the volume counted for that container is more than double the actual volume of drums over-packed within it.

One final example of over-packing is a payload container that was developed to allow more efficient shipment of waste streams with high fissile content [5]. After the Rocky Flats site terminated production operations, impure Plutonium oxides and salts at the Rocky Flats site were declared excess to DOE needs. Safeguards were terminated on this material by blending it with inert materials (making it hard to separate), and packaging it into what became known as a pipe over-pack component (POC), resulting in Attractiveness Level D waste. The POC is essentially a heavy duty 15-30 cm diameter stainless steel pipe, with welded bottom and heavily bolted lid. The POC is then placed in a standard 208-liter drum with wood bracing to center it within the drum. When fissile material is packaged in this configuration, up to 200 g may be shipped in each POC, with no fissile limit on the amount that may be shipped in the TRUPACT-II. Thus, instead of a 325-g limit on fissile material per shipping container, each TRUPACT is limited to <14 X 200-g, or <2.8 kilograms. Again, the volume of the inner container (~50 liters) is much less than the payload container (~200 liters). Figure 2 shows a nominal mix of payload containers emplaced in a disposal room at WIPP.

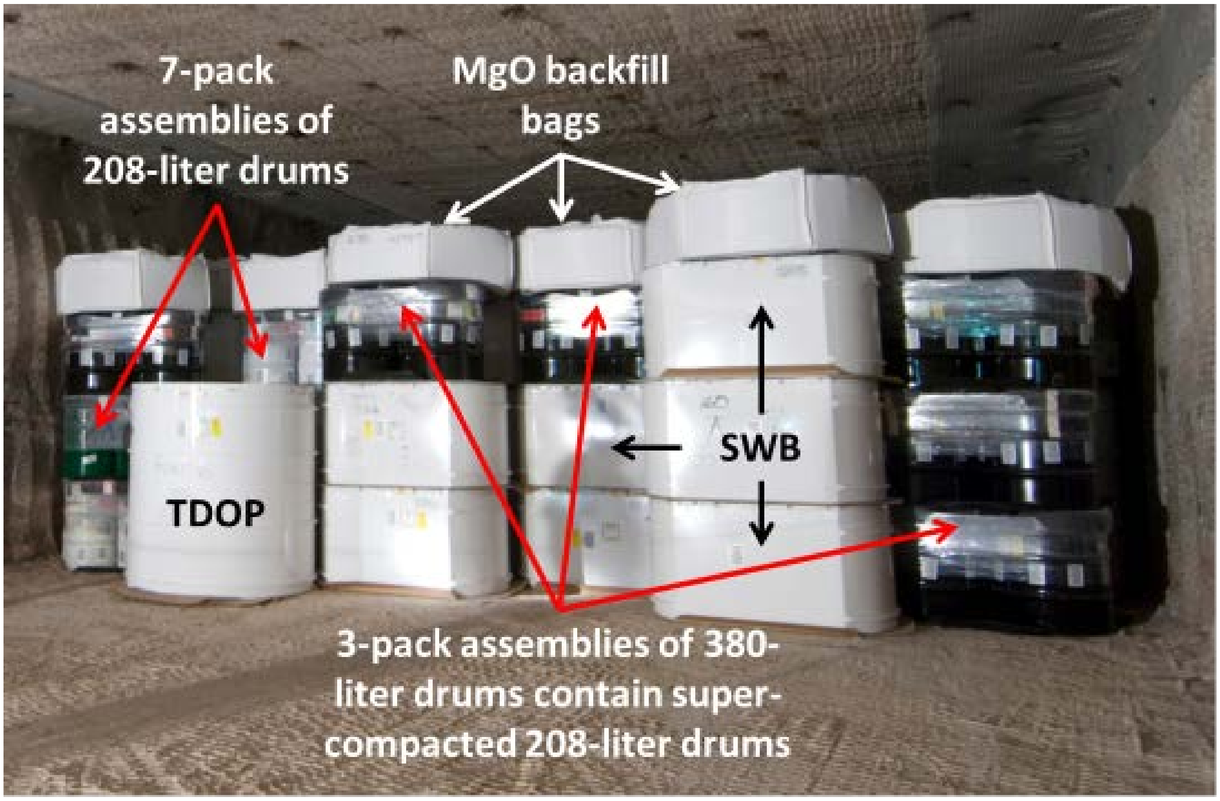

Fig. 2. Typical payload containers emplaced in a disposal room underground at WIPP, showing a nominal payload container type mix.

Table I shows the number of over-packs emplaced in WIPP through May 2013. Also shown are the volumes as counted as the volume of record (the payload container volume), versus the volume if only the inner over-packed containers were counted.

TABLE I. Volume (cubic meters) associated with various over-packed inner containers and their impact on repository volume capacity

	Emplaced Volume of Record	Inner Container Volume	Volume Capacity Used by non-waste volumes
TDOP	25,897	11,510	14,387
SWB	21,735	9,660	12,075
POC	5,224	1,250	3,974

By counting the payload (outer) container volume as the waste volume of record, more than 30,000 cubic meters of non-waste volume is counted against the WIPP volume capacity limit (sum of the last column). This is almost the same volume occupied by two entire waste disposal panels at WIPP. Another way of thinking about this is that almost two of the six filled disposal panels have been used for emplacing the air and/or packaging material outside the inner containers (but still within the payload containers) to date.

CONTAMINATION CONTROL (Worker Exposure Avoidance Affects Repository Capacity) - THE FILL FACTOR

Another significant factor in packaging TRU waste is the liberal use of plastic bags or other contamination control methods during TRU waste processing in a glovebox. Glovebox operations are inherently inefficient and clumsy, and worker protection practices often result in more plastic bags than waste being placed into a drum of newly generated or re-packaged legacy TRU waste. Many containers are not filled to their full capacity. These fill factors account for a significant fraction of the volume of “waste” already emplaced in WIPP.

Directly loaded payload containers packaged for shipment to WIPP are characterized according to the requirements of the waste analysis plan, which is documents compliance with WIPP’s Hazardous Waste Facility Permit issued by the New Mexico Environment Department. That waste analysis plan calls for estimating the contents of the payload container in terms of what are known as material parameter weights. The origin of the requirement to estimate these material parameters comes from the probabilistic performance assessment that DOE is required to perform every 5 years to maintain certification under 40 CFR Part 194, as regulated by EPA. The performance assessment calculates the probabilities that the repository will release radioactivity over a 10,000 year performance period. The probabilities and release amounts are related to the amount of gas generation that results from iron corrosion and bacterial metabolism, which are related to the amount of iron, non-ferrous metals, and cellulose plastic and rubber in the waste matrix itself. These material parameter weights are required to be tracked as each payload container is characterized, and are estimated in one of two ways.

Typically, a visual examination process (regulated under the WIPP permit via procedure) is used to estimate the material parameter weights as each container is loaded by trained and qualified inspectors. If containers are already loaded, the material parameter weights are estimated by trained and qualified observers during examination using real-time radiography (RTR). In either case, along with the material parameter weight estimates for each container, another parameter, known as the fill-factor is estimated and recorded. The fill-factor data quality objective is 5% accuracy.

Figure 3 shows a range of typical RTR images for several waste streams from DOE’s Hanford site. RTR operators are trained to use the highest point of visual waste components in each container as the measure of the fill-factor, which is shown along with each image as a percentage.

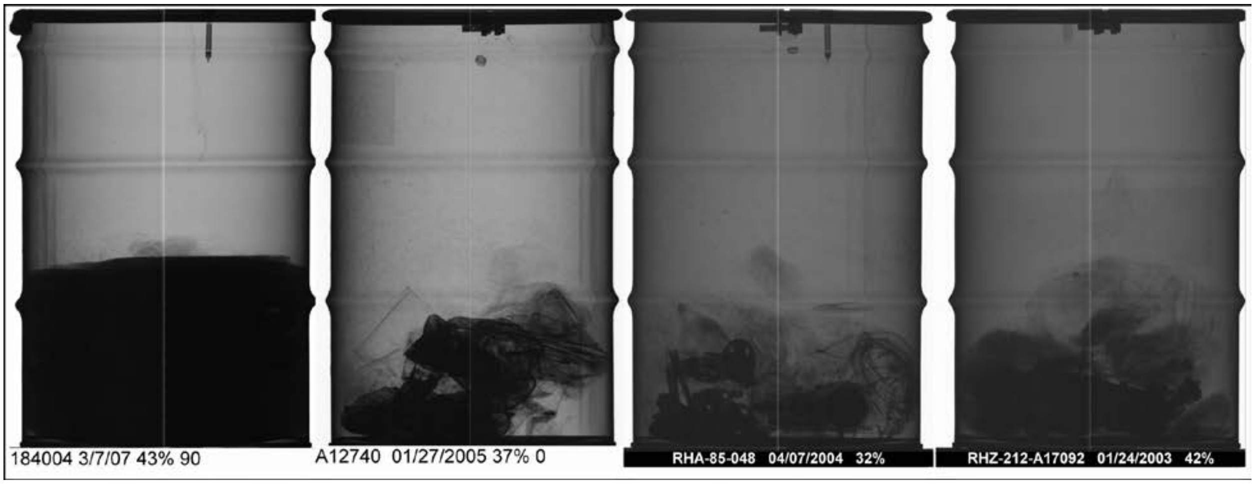

Fig. 3. Real-Time Radiography images of waste streams from Hanford, illustrating the fill-factor concept.

While the space above the dark (more dense) waste materials at the bottom appears to be empty air, in most cases it contains a loose matrix of plastic bag ends (called horse tails) that allow glove box operators to bag-in and bag-out materials to and from the glovebox and the payload containers as they are being packaged. This contamination control practice is used throughout the nuclear industry, and rarely allows operators to fill waste containers to their full capacity.

Because the container-specific fill-factor is estimated via procedure, with a quality assurance pedigree, it is possible to quantitatively estimate the amount of waste volume that has been emplaced in WIPP to date, and compare it to non-waste components. By tallying only the direct-loaded payload containers (not over-packed), and applying a container-specific fill-factor recorded for each, an overall volume of ~11,000 cubic meters (~388K cubic feet) can be attributed to the non-waste volume. This is compared to ~26,800 cubic meters of actual waste volume. The total, 37,800 cubic meters, indicates an overall fill-factor for direct-loaded payload containers of 71% for the TRU waste inventory already emplaced in WIPP. This is almost the same volume occupied by an entire waste disposal panel at WIPP. Another way of thinking about this is that, to date, one of the six filled disposal panels has been used for emplacing non-waste materials in the headspace above the waste.

There is reason to expect that this overall fill-factor will decrease for future waste destined for disposal. A significant fraction of the inventory counted in the above analysis came from the Advanced Mixed Waste Treatment Plant (AMWTP) in Idaho, which employs a super-compactor to crush thin-walled drums into “pucks”. These pucks are then direct loaded into 0.38 cubic meter (100-gallon) drums. These direct-loaded drums (over 34,000 shipped to date) have all been assigned a 100% fill-factor, thereby keeping the overall fill-factor higher than otherwise. When the inventory processed through the AMWTP is exhausted, the fill-factor of waste from the rest of the complex will likely decrease.

VOLUME IMPLICATIONS FOR INCREASING DISPOSAL SPACE IN WIPP

The disposal panel layout and room size at WIPP were designed to accommodate 175,565 cubic meters of waste in the form of payload containers. That capacity was based on early (1970's) seemingly arbitrary estimates of the volume of defense TRU waste that would be created as a result of nuclear weapons activities over a period into the future which could not be known at the time. This estimate was made in the middle of the cold war. It could not be expected to reflect the future reality, wherein US Plutonium production was terminated in the late 1980's, with cessation of cold war stockpile expansion.

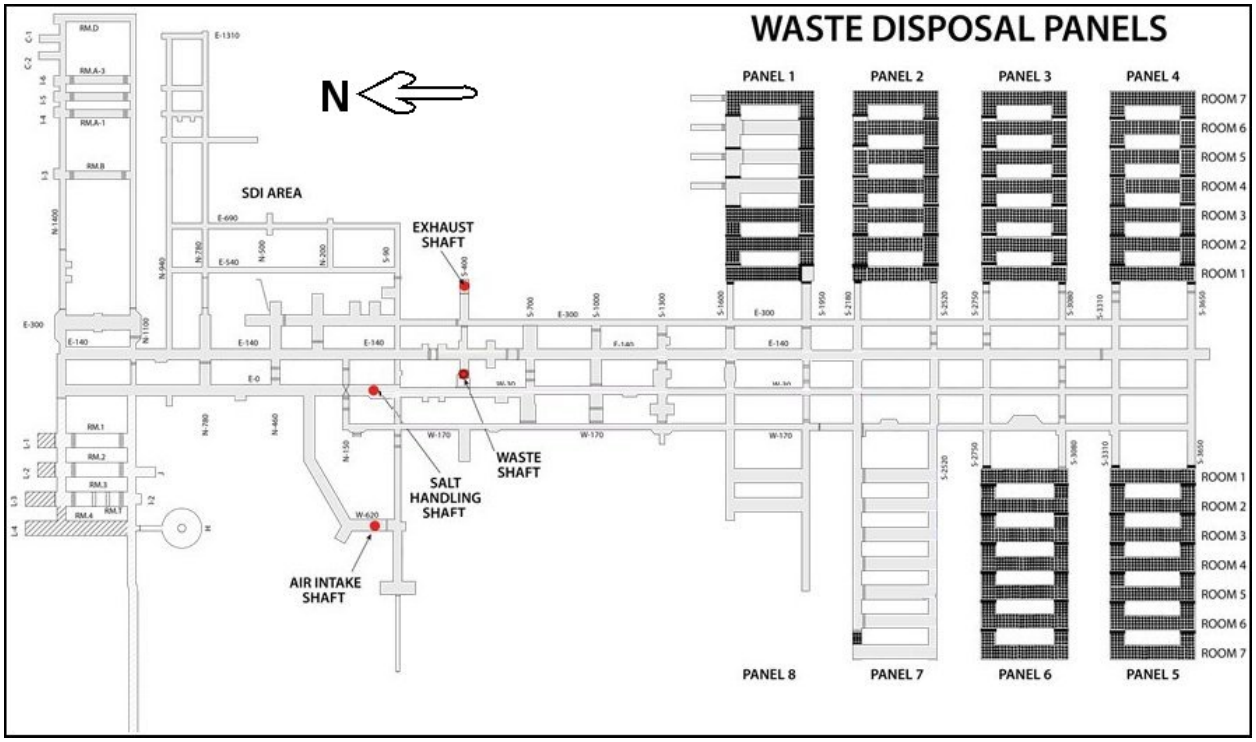

Fig. 4. WIPP layout showing disposal panel and room layout (shaded areas represent contact handled waste emplacement at the time of the 2014 events).

The WIPP disposal room and panel design layout is shown in Figure 4. The nominal 8 disposal panels, with 7 disposal rooms per panel each contain space for about 15-17K cubic meters of contact handled waste as packaged in a nominal payload container mix. Early concepts for two additional disposal spaces (equivalent to panels 9 and 10) planned to use the common cross drifts between the east and west panels (1-4 and 5-8) as disposal space. While this concept would work for contact handled waste emplaced on the floor of the drifts, the geotechnical stability of the ribs along these common (and old) drifts preclude the safe disposal of remote handled waste in horizontal boreholes in the internal pillars [6].

Very early concepts for the design of WIPP in the mid-1970's included waste emplacement at a lower horizon (~150 meters below the current disposal horizon). If this concept were revisited, serious consideration should be given to added access to the new horizon (or horizons), which would involve winze creation and operation, with mining and ventilation challenges as well as multiple transfer operations during waste emplacement. It is unlikely that a practical concept for creating different disposal horizons could be developed below (or above) the existing facility.

Thus, the obvious possibility for creating more space at WIPP is the development of additional disposal panels outside the nominal footprint shown in Figure 4. A recent initiative to create new panels, called 9A and 10A immediately south of Panels 4 and 5 has been tabled as a result of the accidents of February 2014. It is important to note that this concept would not increase available disposal space; it simply would move the available footprint from the common cross-drifts between panels 1-4 and panels 5-8 further south [6].

Proposals to create new disposal space to the east or west of the panel 1-8 footprint have not been developed, but in lieu of different disposal horizons, these options are the only ones remaining. While adding new disposal space east or west of the current footprint would be controversial, there are no known geotechnical constraints that would preclude this possibility. Additional disposal panels either east or west would still be well within the 42 square kilometer (16 square mile) area of the Land Withdrawal Act boundary. The obvious question is how much more space is needed to accommodate the future TRU waste inventory. In light of the way the volume of record is currently calculated, and given the need to change the volume counting practice, this question is difficult to answer.

DOE annually estimates the amount of TRU waste remaining to be emplaced in WIPP and reports this to EPA in compliance with 40 CFR Part 194 criteria [7] (see: http://www.wipp.energy.gov/library/TRUwaste/ATWIR%202015.pdf). The most recent estimate is that 57,600 cubic meters of contact handled waste is "bound" for WIPP. However, this estimate of volume only partially considers the manner in which this inventory will be packaged and shipped. While most waste streams included in the estimate have been containerized, the majority of the 57,600 cubic meters has yet to be packaged into a final form for shipment. If the future packaging of 57,600 cubic meters resulted in a 100% fill factor, and no over-packed containers, the total resulting volume (90,600 already emplaced plus 57,600 future waste) would be 148,200 cubic meters. Compared to the 175, 565 cubic meter volume limit, this would leave about 27,400 cubic meters of unsubscribed capacity. Based on 15 years of packaging experience to meet the WIPP WAC, it is unlikely that a 100% fill factor and zero over-packing of future waste streams can be achieved.

In addition, the 57, 600 cubic meters of future WIPP-bound inventory also includes only a small amount of contact handled TRU waste that may be generated during decommissioning efforts at DOE facilities. It only includes generator site estimates through 2033. With much of the decommissioning at these sites (with ongoing defense missions) planned to begin after 2033, it is likely that any unsubscribed WIPP capacity will be consumed.

CONCLUSIONS

The conceptual planning for WIPP in the 1970's estimated that a volume of 175, 565 cubic meters would be needed for defense TRU waste disposal. This conceptual volume evolved into a hard limit on the capacity of waste authorized by the WIPP Land Withdrawal Act. Over the first 15 years of WIPP disposal operations, about 90,600 cubic meters of contact handled waste has been emplaced. This volume is calculated as the total outside volume of all payload containers that have been shipped to WIPP, and implies that there is about 85,000 cubic meters of volume capacity remaining before the Land Withdrawal Act limit is reached. Almost half of the volume of record is made up of non-waste materials and/or packaging materials and air.

The volume of inner containers inside payload containers shipped to WIPP, which have been over-packed, is about is about 22,400 cubic meters. The overall payload volume of the outer payload containers is about 52,800 cubic meters, a difference of over 30,000 cubic meters, made up of non-waste packing materials and air. The volume of waste inside direct loaded containers is about 26,800 cubic meters, which makes up about 71% of the volume of the containers (average fill-factor). The remaining 29% of volume inside the headspace of the containers is typically contamination control materials, like plastic, or simply air space above the waste matrix. Thus, the combination of over-packing and fill factor makes up almost 50% of the volume already subscribed at WIPP.

While small gains in packaging efficiency may be possible, the reasons for over-packing inner containers are generally valid and appropriate. Likewise, worker protection and contamination control practices cannot be made significantly more efficient. Without a change in the way the volume of record is calculated, WIPP will likely reach its volume capacity limit before the contact handled TRU waste inventory currently identified has been emplaced. This is exacerbated by a WIPP-bound inventory data call cut-off date of 2033. Much of the TRU waste that may result from decommissioning active defense-related DOE sites has not been counted in the current projection of future waste streams beyond 2033.

The US Cold War legacy risks are being permanently reduced by WIPP. The nation would be well served if changes in the manner of counting waste volume were made now to eliminate the air and non-waste components counted against the WIPP waste capacity from this point forward. Reconsidering the volume assigned to the already emplaced repository inventory would also be a positive move for the nation. Finally, a risk-based redetermination of the legal volume limit on the WIPP disposal capacity that becomes codified into law would also serve the nation well. WIPP is an important component to reduce risk and terminate costly safeguards and security requirements for the TRU wastes of the DOE complex. Its volume capacity should be reconsidered.

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